LABORATORY PRACTICE

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VOL. 10 No. 5 Published Monthly MAY 1961

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With over 40 years' experience in design and construction, we have now completely restyled our general purpose furnaces and added several new types to the range. Operating temperatures have been increased and new models introduced for use up to 1500°C. Larger sizes are now available and furnaces have, in general, greater useful working spaces due to improved design. High performance, coupled with very robust construction and reliability make the furnaces equally suitable for laboratory and industrial applications. We also supply special purpose furnaces for coal and coke testing, differential thermal analysis of minerals, and sulphur and halogen determination by the Carius method.

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ASK FOR PUBLICATION 620

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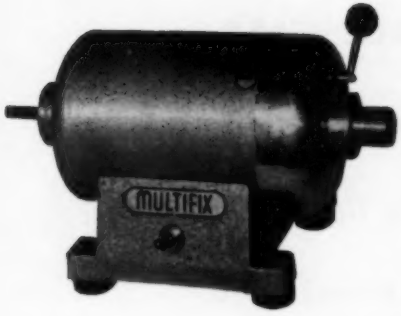

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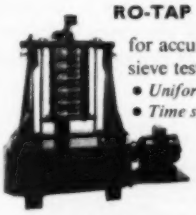

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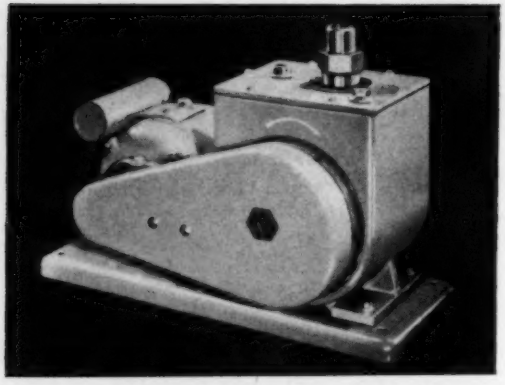

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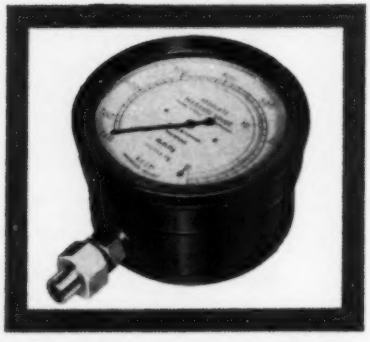

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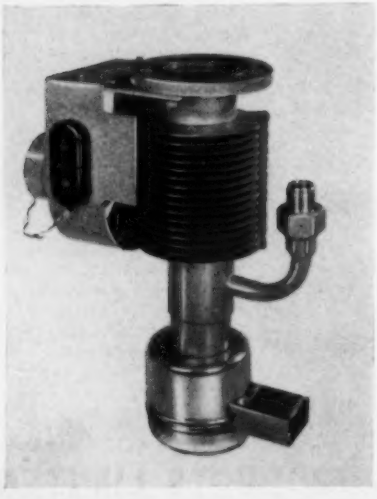

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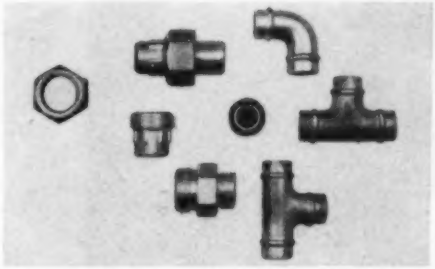

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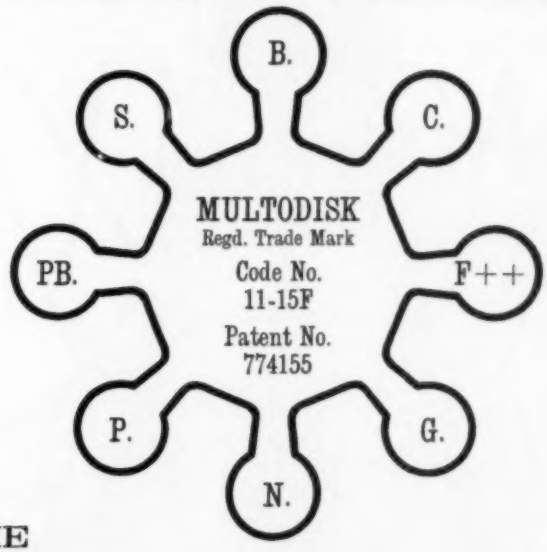

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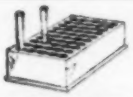

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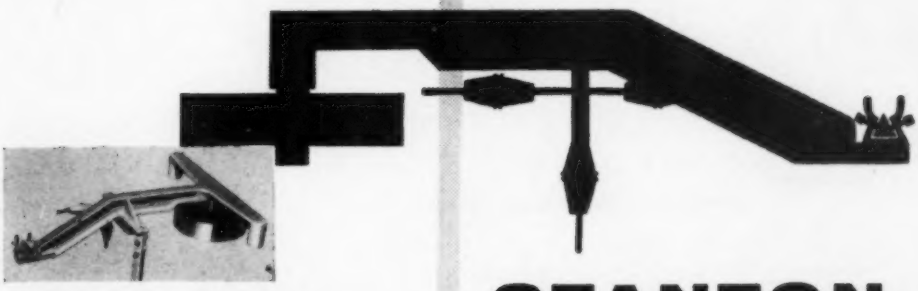

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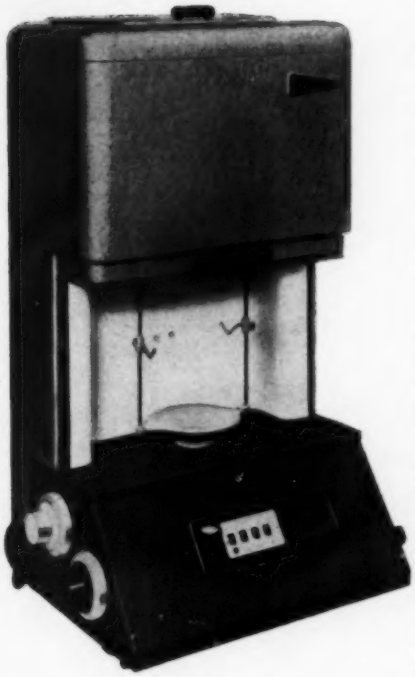

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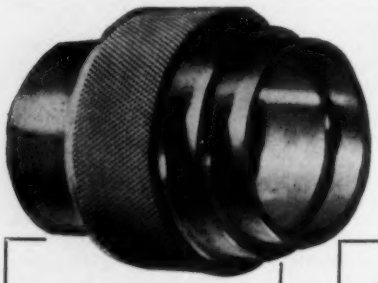

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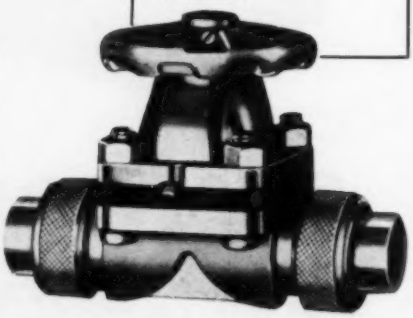

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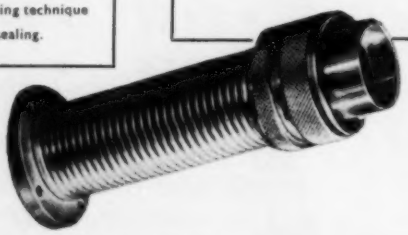
FLEXIBLE CONNECTIONS
Flexible metallic bellows connections fitted each end with either screwed unions or vacuum flanges.



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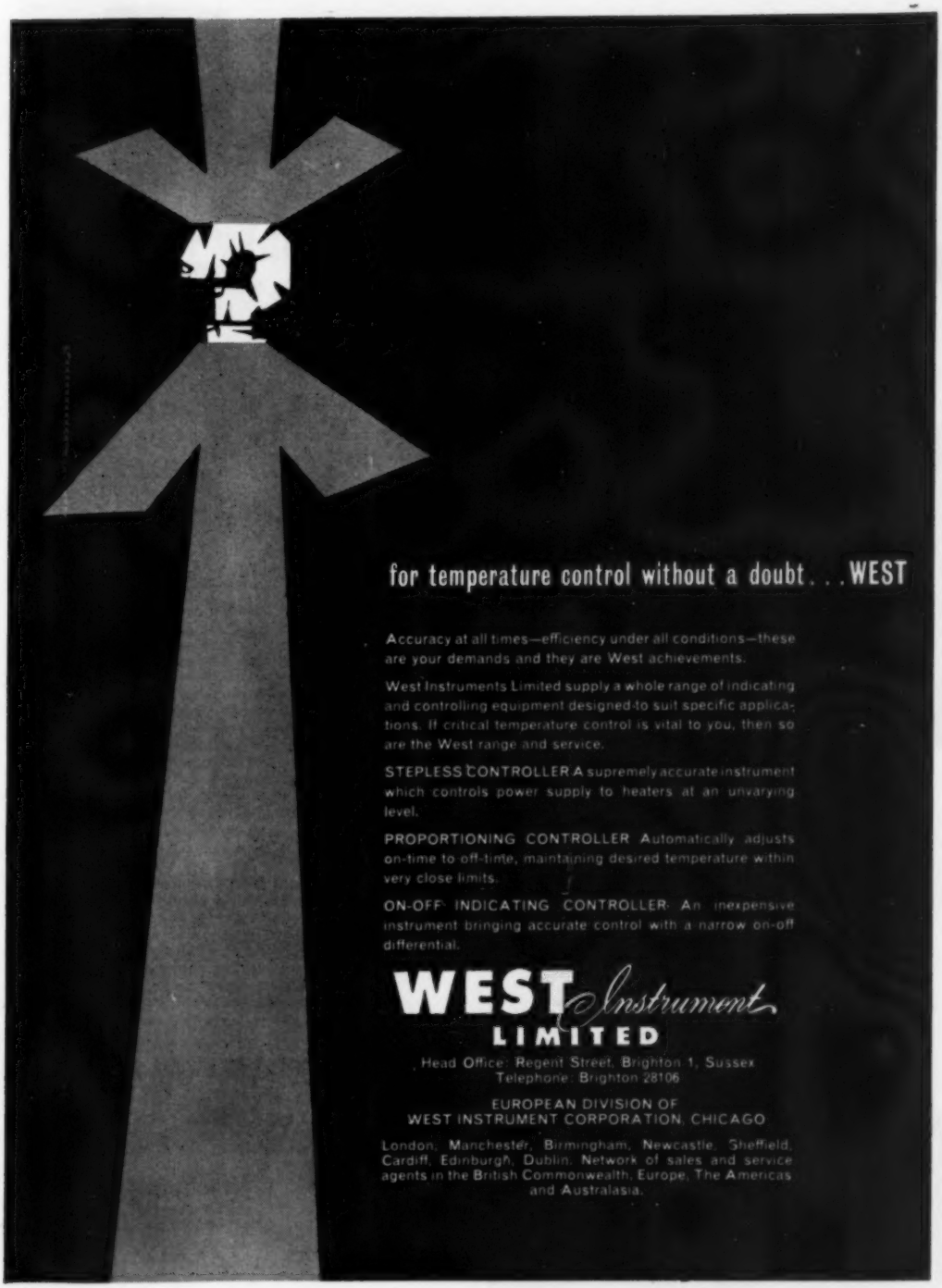
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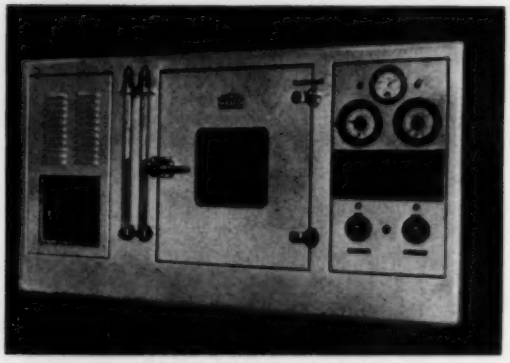

Catalogue No. 755 R Humidity Cabinet with automatic control and refrigeration.

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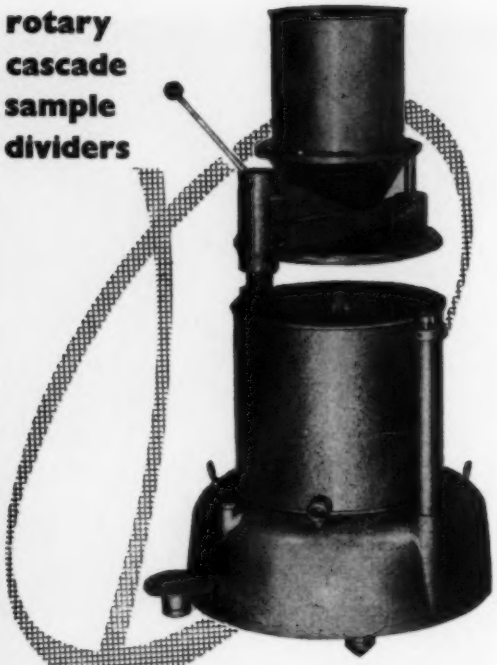

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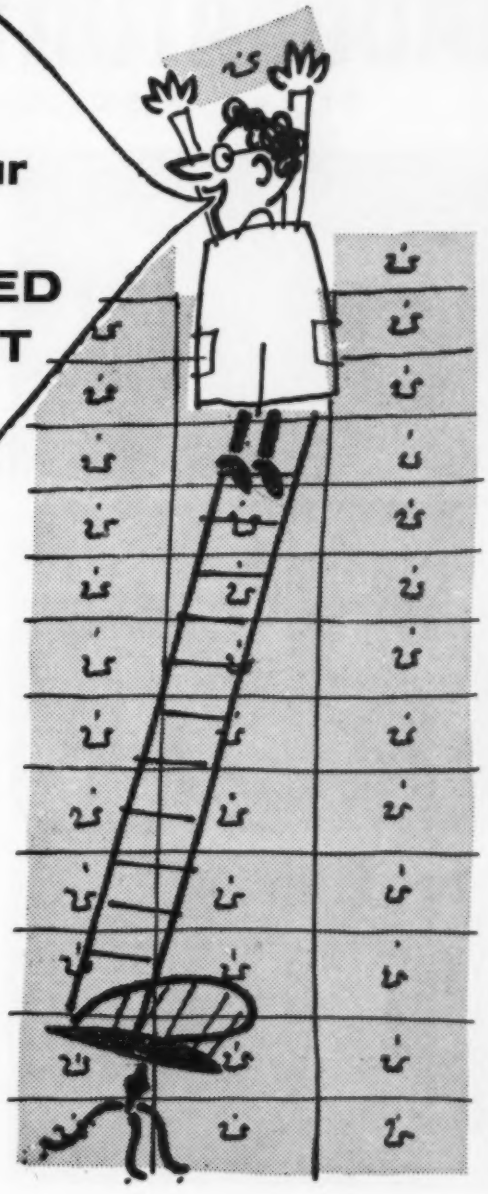

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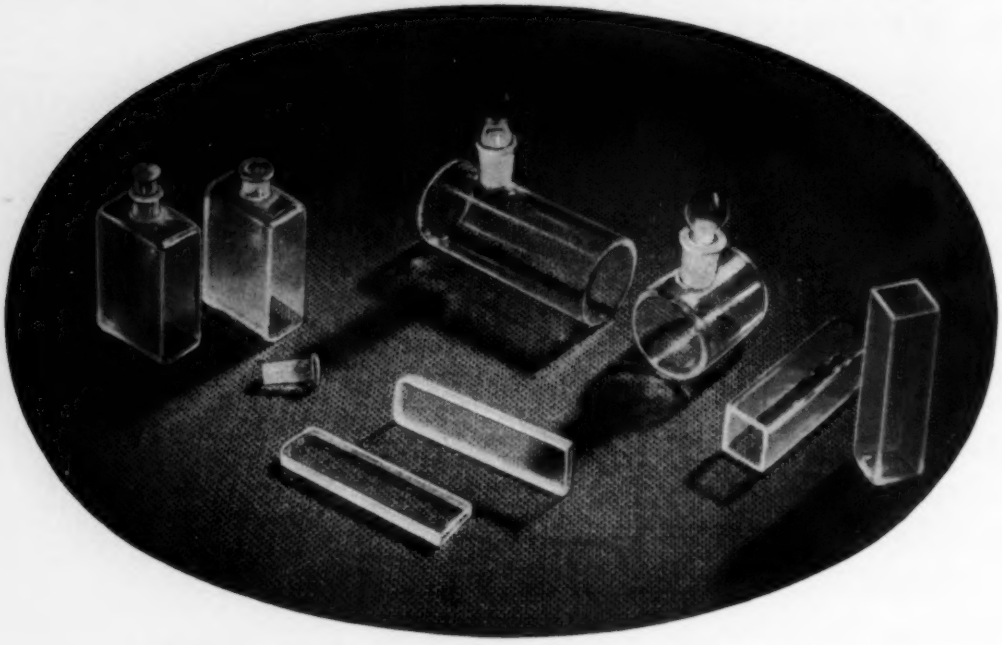

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MR. GORDON WATKINS

We regret to report the sudden death, at the age of 52, of Mr. Gordon Watkins, a Director of United Trade Press Ltd., publishers of Laboratory Practice.

Mr. Watkins has been a member of the company for 25 years and was concerned with the development of the entire group of the U.T.P. trade publications.

Mr. Watkins was also a Director of U.T.P. Exhibitions Ltd., organizers of the Laboratory Apparatus and Materials and other Exhibitions, and a Director of Tailor and Cutter Ltd., publishers of the Tailor and Cutter *weekly trade journal.*

He leaves a widow, son and daughter.

Fellows of the Royal Society

The following are among those who have been elected Fellows of the Royal Society; the remaining elections will be published next month:

Prof. James Baddiley.—Professor of Organic Chemistry in the University of Durham, King's College, Newcastle upon Tyne. Distinguished for his researches in organic and biochemistry, particularly in the field of co-enzymes, nucleotides, and bacterial cell-wall constituents.

Prof. Harold Everard Monteagle Barlow.—Dean of the Faculty of Engineering, and Pender Professor of Electrical Engineering and Director of Laboratories in the University of London, University College. Distinguished for his work on engineering aspects of microwaves particularly wave guides and semi-conductors.

Prof. Maurice Stevenson Bartlett.—Professor of Statistics in the University of London, University College, Department of Statistics. Distinguished for his contributions to the methods of mathematical statistics and their application to physical and biological science.

Prof. Rupert Everett Billingham.—Professor of Zoology in the University of Pennsylvania, Department of Zoology, Philadelphia, U.S.A. Distinguished for his studies on the pigmentary system of mammals and on tissue transplantation.

Prof. Clifford Charles Butler.—Professor of Physics in the University of London, Imperial College of Science and Technology, Department of Physics. Distinguished for his researches on the elementary unstable particles in cosmic rays.

Dr. Joseph Chatt.—Head of the Inorganic Chemistry Department, Akers Research Laboratories, Imperial Chemical Industries Ltd., Welwyn, Hertfordshire, and Group Manager of the Heavy Organic Chemicals Division. Distinguished for his work on the chemical and physical constitution of co-ordinated metallic compounds.

Prof. Brian Hilton Flowers.—Langworthy Professor of Physics in the University of Manchester, Department of Physics. Distinguished for his numerous contributions to theoretical nuclear physics, especially the shell model of the atomic nucleus.

Dr. Louis Harold Gray.—Director of the British Empire Cancer Campaign Research Unit in Radiobiology, Mount Vernon Hospital and Radium Institute, Northwoods, Middlesex. Distinguished for his contributions to the effect, of radiations on cells and to radiotherapy.

Dr. Sidney Henry Haughton.—Inter-African Scientific Correspondent for Geology, Commission for Technical Co-operation in Africa, Pretoria; formerly Director of the Geological Survey of South Africa. Distinguished for his many contributions to South African geology, especially in the fields of palaeozoology, stratigraphy and economic geology

Prof Rodney Hill.—Professor of Applied Mathematics in the University of Nottingham, Department of Mathematics. Distinguished for his contributions to the theory of continuous mediums, particularly to the plasticity of metals.

Dr. Howard Everest Hinton.—Reader in Entomology at the University of Bristol, Department of Zoology. Distinguished for his work on insect biology, particularly on the larval stages of insects, and on classification and morphology of Coleoptera, Lepidoptera and Diptera.

Dr. Robert George Spencer Hudson.—Research Fellow at the University of Dublin, Trinity College, Department of Geology. Distinguished for his stratigraphical and palaeontological researches in the carboniferous of the north of England and in the Mesozoic rocks of the Middle East.

Mr. Christopher Frank Kearton, O.B.E.—Managing Director, Courtaulds Limited, Coventry. Distinguished for his work on chemical engineering characteristics of volatile uranium products and for technological development in the textile industry.

Dr. Heinz London.—Deputy Chief Scientific Officer at the Atomic Energy Research Establishment, Harwell. Distinguished for his work on superconductivity, on liquid helium and on the separation of isotopes.

Prof. Montague Maizels.—Professor of Clinical Pathology in the University of London, University College Hospital Medical School, Department of Clinical Pathology. Distinguished for his investigations into the mechanisms by which the electrolyte composition of animal cells is maintained.

LABORATORY EQUIPMENT TEST REPORT—No. 42

ELECTROPHORETIC DENSITOMETER

Manufacturers: Baird & Tatlock (London) Ltd., Chadwell Heath, Essex.

Price: £77. 10s. 0d.

Introduction

It is a great convenience in preparing permanent records to be able to measure directly the amounts of substances in the bands separated by electrophoresis from mixtures applied to strips of filter paper or Cellophane. This Baird & Tatlock densitometer is designed to examine suitably stained strips by measuring the visible light passing through the strip. The most important application of such measurements is in the determination of stained bands containing proteins, and the instrument was tested for its ability both to resolve fairly closely spaced bands on filter paper and on Cellophane and to reproduce its results.

Description

The instrument is essentially a device for passing the stained strip at a controlled rate between a light source and a barrier-layer photocell which is connected to a mirror galvanometer and also to a socket outlet through which the output from the photocell can be connected to an amplifier and chart recorder.

The body of the instrument is robustly made of cast aluminium and houses the galvanometer and its lamp, a synchronous motor and a transformer. The galvanometer suspension can be locked with a small handle on the side of the case and its deflection can be adjusted by a zeroing knob on the top of the case just below the light source. The strip, which may be up to 38 cm. long, is held by a split inner ring of Perspex in a detachable Perspex cylinder that is placed in position on top of the body casing. The cylinder has a milled edge which is engaged by the rubber driving wheel of the motor. The light source, a 6 V. filament lamp, is mounted in the centre of the Perspex cylinder and the light is directed through the wall of the cylinder towards a turret housing the photocell. The intensity of the light source can be varied by means of the potentiometer on the front of the instrument. The turret consists of two rotatable sleeves, one carrying four filters and the other four slits of different widths.

Operation

To use the densitometer a stained strip is soaked in oil, drained of surplus oil and placed in the circular holder. (It is important to avoid trapping air bubbles on the paper, but at the same time it is necessary to prevent excess oil from running down the sides of the holder and thus reaching the driving wheel as this allows it to slip). The holder is put in position, the light switched on and a suitable filter selected by turning the knob on the top of the turret. The outer sleeve of the turret is then turned to prevent light reaching the photocell and the galvanometer zero knob is adjusted to give a reading of 100. A suitable slit width is then selected (the smallest slit gives the best definition and was used in all trials), an unstained portion of strip is placed in the light beam and the intensity of the light adjusted by means of the potentiometer to give a reading of 0 on the scale. The motor is then switched on and the stripholder allowed to rotate. Rotation can be stopped by pressing a knob on the case and, as the upper rim of the holder is marked at 1° intervals and these marks pass across a reference line, it is possible to arrest the strip at regular intervals to take readings. It takes about ten minutes for the stripholder to make a complete revolution, and about the same time to scan a 15-20 cm. strip and take readings at every degree interval. When a chart recorder is being used it takes about five minutes to prepare the recording from a 15-20 cm. strip, and although the definition achieved was satisfactory there would probably be some advantage in a slightly slower traverse.

Preparation of Stain Density Curves from Proteins Separated by Electrophoresis

The instrument was used to prepare stain density curves from paper strips on which blood serum proteins and whey proteins had been separated. The strips were stained with bromphenol blue and rendered translucent with paraffin oil. No difficulty was experienced in

Baird & Tatlock electrophoretic densitometer

ORIGINAL CONTRIBUTION

resolving even quite closely spaced bands. Thus, for instance, a satisfactory separation was obtained of the bands containing lactoglobulins A and B. Repeated determinations on the same strip showed a good degree of reproducibility. The densitometer proved quite stable both electrically and optically, and it performed satisfactorily when connected to a chart recorder.

Attempts to prepare acceptable stain density curves from Cellophane strips on which blood serum proteins had been separated were less successful. The strips received a normal loading of protein and were stained with Ponceau S and rendered translucent with Whitemor 120 oil. The stained bands were clearly visible to the naked eye, but the density of staining proved insufficient to produce a satisfactory curve.

Several workers used the instrument to take readings manually. All were agreed that it was easy to use, but that it would be even easier if the pressure required to actuate the knob that arrests the rotation of strip was not so great. Operation of this knob became particularly fatiguing when readings were required at 1° intervals.

Conclusion

The densitometer is of simple, straightforward design. It is solidly constructed and of pleasing appearance. It was found to do its job satisfactorily, though minor modifications to the cylinder arrestment mechanism would make it much easier to use as a manual instrument, and to the drive and motor speed for use in conjunction with a chart recorder.

OUR CONGRATULATIONS TO—

Sir Charles Dodds, M.V.O., F.R.S.

Sir Charles Dodds has been appointed chairman of the Advisory Council of Scientific Research and Technical Development in succession to Prof. J. L. M. Morrison of the University of Bristol.

Sir Charles was elected to Fellowship of the Royal Society in 1942 and has been Courtauld Professor of Biochemistry in the University of London and director of the Courtauld Institute of Biochemistry at the Middlesex Hospital since 1925. He is also a member of the Scientific Advisory Committee of this journal.

The Council, consisting of 11 scientists and engineers from universities and industry and eight scientists drawn from the staffs of the War Office and other Ministries, was set up when the War Office accepted much greater responsibilities in the field of research and development on the abolition of the Ministry of Supply in 1959.

Prof. A. A. Miles, C.B.E., F.R.S.

We also offer our heartiest congratulations to Prof. A. A. Miles, who became a member of our Scientific Advisory Committee last year, on his election to the Fellowship of the Royal Society.

Prof. Miles has a distinguished career in bacteriology and is well known as a co-author of the classical 'Topley and Wilson's *Principles of Bacteriology and Immunity*.'

Prof. Miles was successively demonstrator in bacteriology at the London School of Hygiene and Tropical Medicine, in pathology at Cambridge, and Reader in bacteriology at the British Post-graduate Medical School in Hammersmith. He was elected to the chair of bacteriology at University College Hospital Medical School in 1937 and was appointed Director of biological standards at the National Institute for Medical Research in 1945. He later became Deputy Director of this Institute and in 1952 was appointed Director of the Lister Institute of Preventive Medicine, an appointment which he still holds.

His main scientific work has been in the antigenic analysis of *Brucella* organisms and, in collaboration with Pirie, he demonstrated that the essential endotoxin and main antigen in *Brucella melitensis* was a lipopolysaccharide complex containing polypeptides. More recently he has been interested in the problems of non-specific immunity especially in relation to the early stages of infection and the mechanism of early inflammation.

During the war, he worked with the Emergency Pathological Service on problems of wound infection. He was honorary director of an M.R.C. unit of wound infection at the Birmingham Accident Hospital.

For a working scientist, Prof. Miles has managed to fit in a large amount of important administrative work throughout his whole career, so that his F.R.S. is all the more an achievement.

Royal Society and Nuffield Foundation Awards

Awards under the Royal Society and Nuffield Foundation Commonwealth Bursaries Scheme have been made as follows:

Mr. J. Attridge, lecturer in zoology, Birkbeck College, to assist him in doing further work on the dinosaur beds, and other fossil reptile deposits, of the Karroo System.

Dr. M. M. Chakrabarty, reader in applied chemistry, Calcutta University, to assist him in studying new techniques for the investigation of fatty oils at the Prairie Regional Laboratory, Saskatoon (and possibly also at the Paint Research Station, Teddington).

Prof. J. H. O. Day, professor of zoology, University of Cape Town, to enable him to study type specimens at the British Museum (Natural History) in connection with the preparation of a monograph on the South African Polychaeta.

Dr. W. H. Elliott, fellow, biochemistry department, John Curtin School of Medical Research, Australian National University, Canberra, to assist him in visiting Cambridge to study microbiological techniques.

Dr. D. E. Hoare, lecturer in physical chemistry, Queen's College, University of St. Andrews, to enable him to study reactions of hydroxyl radicals with hydrocarbons at the National Research Council, Ottawa.

Mr. C. R. Horrell, of the Department of Agriculture, Uganda, to enable him to visit Queensland to study the development of tropical pasture grasses and legumes for the production of temporary leys.

Dr. C. A. Hurst, senior lecturer in mathematical physics, University of Adelaide, to assist him in visiting Edinburgh to investigate the properties of relativistic two body equations.

Prof. J. C. Jaeger, professor of geophysics, Australian National University, Canberra, to enable him to carry out a study of stresses in deep mines and correlation with seismic observations, at the Bernard Price Institute, Johannesburg.

Mr. I. C. McKellar, of the New Zealand Geological Survey, to assist him in studying glacial geology, Pleistocene stratigraphy and techniques in glaciology in British Columbia.

Dr. S. S. Qadri, reader in zoology, University College of Science, Osmania University, to enable him to learn protozoological techniques at the London School of Hygiene and Tropical Medicine.

ORIGINAL CONTRIBUTION

A TECHNIQUE FOR BREEDING THE LABORATORY MOSQUITO AEDES AEGYPTI L.

by A. Kirkwood

Ministry of Agriculture, Fisheries and Food, Central Veterinary Laboratory, Weybridge, Surrey.

THE yellow fever mosquito *Aedes aegypti L.* is used in many laboratories for investigating the efficacy of insecticides. It is one of the easiest of the blood sucking flies to breed and its life cycle is such that both the larvae and the adult flies are readily available. With the advent of the more recent organophosphorus insecticides for systemic use in the veterinary field, both the larvae and adults have become almost indispensable. In this laboratory the mosquito is being used to study the effect and mode of action of systemic insecticides intended for the control of the warble fly in cattle.

Techniques for breeding the fly have been reviewed by Trembley (1955) and Christophers (1960). The usual practice is to culture the larvae in open dishes or trays of water in which they will eventually pupate over a period of days. The pupae must be removed from the water before the adults emerge and this is generally done by pipetting them into small dishes of water which are then placed in a cage. This is a tedious task which requires time and labour that is not always freely available, and furthermore a large number of trays have to be maintained to supply the many flies that may be required for a test on any one day, particularly if those flies are to be of the same age. In order to avoid the laborious task of collecting pupae, McKiel (1957) bred his larvae in a small tank of water and allowed the flies to emerge directly into a cage held above. The technique described in the present paper is also designed to avoid picking out pupae and to supply flies or larvae of a standard size and age suitable for testing insecticides on a given day.

The cultures are maintained in a constant temperature room at 25°C. ± 0·5°C. and 65-70 per cent relative humidity. Under these conditions the flies complete their development in nine days.

For flies from any one culture to emerge together, it is obviously necessary that the larvae should pupate together. It is, however, difficult to produce a high percentage of pupation in any one batch of larvae in a period shorter than two days. Haddow and Gillet (1959) found that larvae from eggs which had been laid over a period of ten minutes pupated over a period of 46-49 hours and that these pupae emerged over a period of 51-55 hours. Granett and Haynes (1944) showed that standard numbers of larvae would pupate within a few hours of each other if fed with measured amounts of food and kept at a constant temperature, and that flies would emerge over a period of two days. If the larvae are to pupate together it is clearly desirable to start cultures with eggs that will hatch together.

Eggs

In order to obtain eggs a glass culture dish 3 in. in diameter and 2 in. deep, lined with filter paper and half filled with water, is placed for 24 hours in a stock cage of fed flies. The eggs are laid in a heavy ring on the filter paper at the surface of the water. A great advantage in using *Aedes* is that having allowed the eggs to mature, which takes three to four days from oviposition (Shannon and Putnam, 1934), they can be stored for some considerable time and when larvae are required the eggs are simply submerged in water. There is, however, a great variation in the hatching response (Gillet, 1955a and b), and as it is desirable to begin a culture with young larvae of the same age, a further stimulus other than submerging the eggs in ordinary water is necessary. A reduction in the oxygen content of the water will provide this factor, and Burgess (1959) has shown that a greater percentage of eggs will hatch if placed in boiled water that has been cooled. He also showed that more larvae will hatch from eggs that have been stored in a humid rather than a dry atmosphere. Eggs can in fact be stored for as long as six months but their viability decreases with time (Christophers, 1960), and it is not worth keeping them for more than three months. Our practice is to remove the oviposition dish at the end of 24 hours, decant the water, and keep the eggs on the filter paper in a damp condition for three days at room temperature to allow the eggs to mature. They are then slowly air dried and stored in a petri dish held over a pad of damp cotton wool in a desiccator. When larvae are required a strip of filter paper containing sufficient eggs is placed at 25°C. in deoxygenated water that has been recently boiled for 30 minutes and kept sealed in a narrow necked bottle. Having placed the eggs in this bottle of water it is important to reseal the bottle at once to prevent absorption of oxygen.

After one hour most of the eggs will have hatched and are then removed, leaving larvae of the same age ready to be cultured.

Larvae

The larvae are reared in flat penicillin flasks containing approximately 500 ml. of water to a depth of 1 in. These circular glass flasks are 7 in. in diameter, 4 in. deep and are fitted with side spouts plugged with cotton wool. They have been found far more satisfactory than open trays. The larvae can easily be seen, particularly if a light is placed behind the flask, when they will rapidly swim to the front, and being entirely enclosed the cultures are escape proof if any fly should

the end of day 7. The cultures are then simply poured

Summary

TABLE I

Percentage Pupation and Emergence from different sizes of Larval Populations

Figures are those relating to standard flies suitable for use in insecticide tests.

No. of Larvae per Flask	*Culture No.*	*No. of Larvae Pupating on days*				*No. of Larvae Pupated by Day 7*		*No. of flies emerging on days*				*No. of Flies emerged by Day 9*	
		5	6	7	8	*Total*	%	7	8	9	10	*Total*	%
50	1	0	36	45	45	228	91·2	0	35	45	45	220	88·0
	2	0	30	46	46			0	31	45	45		
	3	0	32	48	48			0	40	43	43		
	4	0	40	46	46			0	28	44	44		
	5	0	22	43	43			0	21	43	43		
100	1	0	55	94	94	481	96·2	0	51	94	94	467	93·4
	2	0	87	95	95			0	59	93	94		
	3	0	70	99	99			0	23	94	100		
	4	0	95	100	100			0	37	97	100		
	5	0	49	93	93			0	81	89	91		
150	1	0	60	100	149	507	67·6	0	30	85	150	409	54·5
	2	0	58	82	104			0	7	69	95		
	3	0	118	130	125			0	37	105	125		
	4	0	63	124	124			0	12	89	109		
	5	0	52	71	83			0	5	61	89		
200	1	0	104	131	133	422	42·2	0	21	105	136	362	36·2
	2	0	24	58	76			0	12	40	71		
	3	0	23	90	120			0	10	56	85		
	4	0	47	65	122			0	10	97	125		
	5	0	65	78	93			0	10	64	67		
300	1	0	10	12	25	187	12·4	0	1	2	6	118	7·8
	2	0	21	59	95			0	7	25	69		
	3	0	5	11	46			0	2	5	13		
	4	0	36	84	96			0	21	64	66		
	5	0	0	21	56			0	16	22	34		

prematurely emerge. A further advantage in using these flasks is that a great deal of shelving can be dispensed with as eight or more can be safely stacked.

The hatched larvae are suspended in a petri dish of water so that they may be drawn into a pipette. This pipette has a bulb blown in it to take about 20 ml. and it is fitted with a large rubber teat so that after one depression the required number of larvae can be rapidly taken in and transferred to a flask. After a little practice 100 larvae can be so transferred in less than one minute.

The number and size of the flies produced depends on the population density of the larval culture and it will be seen (Table I) that 100 larvae per flask is the best practical number to use to give a maximum emergence of flies over a reasonably short period.

Various diets, such as infusions of hay or bread, have been used to feed the larvae. Christophers (1960) prefers a mixture of ground dog biscuit and Bemax.

Whatever the choice of food may be, the great danger is the formation of scum, particularly that which may form overnight. This will rapidly kill the larvae. Some workers prevent this by bubbling a continuous flow of air into the culture, but this is not necessary if no more food than is needed is supplied. We use a finely ground dog biscuit and approximately 0·3 g. of this is measured and introduced by means of a spoon of such a size to hold this amount into each culture after the larvae have been introduced, and a further 0·3 g. is added three days later. The culture water should be slightly turbid in appearance and it is sometimes necessary, if it should become too clear by the fourth or fifth day, to add a little more food. Pupation begins on day 6 and most of the larvae will have pupated by

the end of day 7. The cultures are then simply poured into a sieve, washed in tap water and transferred into a small dish of water 2 in. deep which is then placed in a cage for the next 48 hours. The cage made of mosquito netting is described elsewhere by Kirkwood (1960).

Adult Flies

Flies will emerge on days 8 and 9 and are provided with a pad of cotton wool soaked in 10 per cent sucrose solution. This pad is renewed every three or four days. Stock flies are offered a blood meal when they are three days old and thereafter twice a week at intervals of three or four days. A guinea pig is anaesthetized by an intraperitoneal injection of Nembutal*, and the hair on its belly is clipped short. It is then laid on top of the fly cage for 30 minutes during which time the mosquitoes will feed to repletion through the netting of the cage. The oviposition dish is placed in the cage on the third day after the first blood meal, when the flies will be ready to lay their eggs (Putnam and Shannon, 1934). A single cage of 1,000 flies is set up each week and discarded when four weeks old. Four cages are thus maintained and these will supply many thousands of eggs each week.

*Nembutal from Abbott Laboratories Ltd.

Summary

A simple method of rearing *Aedes* larvae and adults suitable for testing insecticides is described. Standard numbers of larvae cultured in flasks of water are fed with dog biscuit. The majority will pupate on day 6 and 7 when they are transferred together into cages. A minimum handling of pupae is therefore required.

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BOOK REVIEWS

A Laboratory Handbook of Blood Transfusion Techniques, by A. Derek Farr, F.I.M.L.T., A.I.S.T. London: William Heinemann, Medical Books Ltd. 1961. pp. 135 + xi. 17s. 6d.

This useful little book clearly covers all the laboratory aspects of handling and preserving blood and all other common transfusion solutions. Much useful information otherwise difficult to find is accurately set out and there are no notable technical omissions. The serological section is deliberately very short, for many books deal with it, and there are helpful sections on transmission of disease and on transfusion reactions.

Primarily intended for technologists in large blood banks, it would be quite often referred to in most hospital laboratories.—JOHN ENTICKNAP.

Practical Heredity with Drosophila, by Gordon Haskell, Ph.D. Edinburgh and London: Oliver and Boyd. 1961. pp. 124 + xii. 10s. 6d.

This book is primarily aimed at 'teachers in schools and colleges where class work in elementary practical genetics is provided'. Accordingly, it contains plenty of advice on methods of rearing and handling *Drosophila* colonies with the minimum of apparatus. With few exceptions, the manipulations are clearly explained and one feels that anyone with biological training could undertake the various 'exercises'.

Most of the later experiments are designed to illustrate various fundamental points of formal genetics; but little is said about theory, which the reader is presumed to study elsewhere. There is, indeed, a glossary, but there are some discrepancies on the levels of information provided. Thus, one can hardly imagine anyone likely to use the book looking up 'gene' or even 'recessive'; on the other hand, 'non-disjunction' and 'RK values', which are mentioned in the text, are not included.

As a practical handbook, this compresses a great deal into a small compass (small 8vo: 12·5 × 18·5 cm.). Apart from the manipulative hints, the lists of mutants and the short statistical section will be found useful.—J. R. BUSVINE.

Section Cutting in Microscopy, by H. F. Steedman, Ph.D. Oxford: Blackwell Scientific Publishers. 1960. pp. 172. 21s.

The author has written a book for the microtomist which, it is intended, shall assist workers in the production of good sections with the best preservation of the histological and biochemical characteristics of the tissue. As many contingencies as the microtomist is likely to meet are covered well, and good advice and descriptions of a wide range of techniques applicable to almost all animal or plant tissues are given with clarity and conciseness. The book is very readable and besides forming a handy reference manual gives a fund

of basic information about the subject which will undoubtedly save many of its readers tedious searches of the literature and much wasted material. It is written from a background of 30 years experience in the techniques of microtomy and students of the subject will find chapters 8-18, 24 and 25 very helpful. These deal with detailed techniques through the cutting of the sections to mounting them on slides. The errors that can be made and the difficulties that may be met are listed and clear instructions for rectifying or overcoming them are given. In addition there are helpful hints on ways of improving the quality of the sections with appropriate stress on the care necessary to keep a good edge on the knife.

The theory of section cutting is adequately covered in the second part of the book, and there is a short section of historical interest at the beginning of the book. The routine microtomist and the research worker also will find much to their advantage including several hitherto unpublished techniques and descriptions of the use of infiltrative media not routinely used. Some of these are of particular use for the cutting of unusual or difficult material.

For the specialist wishing to prepare sections of material with peculiar difficulties, e.g. eggs, eyes, or insects there is a useful chapter concerned with special techniques suited to these problems.

A chapter is devoted to the technique of using each of the following media for infiltration: paraffin wax, ester wax, polyester wax, water soluble waxes, urea-formaldehyde resin and methacrylates, as well as techniques with frozen sections and gelatin sections, and double embedding techniques with agar and ester wax, and celloidin and paraffin wax. A short chapter deals with the cutting of ultra thin sections for electron microscopy. In addition there are instructions on aspects such as knife sharpening (including new methods some of which are still experimental), the production and use of glass knives and section adhesion. References are appended to the chapters when appropriate and there is a glossary of terms used in microtomy and an adequate index as well as a list of reference books and a list of suppliers of the chemicals mentioned in the book.—H. E. H. JONES.

An Introduction to Pharmacology, by J. J. Lewis. Edinburgh and London: E. & S. Livingstone Ltd. 1960. pp. 826 + xii. 55s.

In a rapidly advancing subject like pharmacology new text-books are always welcome to bring the reader up to date and save him the trouble of looking up individual papers on recent developments. Lewis's book is admirable from this point of view. The advantages however go further. The style is simple and the author has a gift for making difficult subjects appear eminently easy. The book is evenly balanced. Each chapter has received the same careful treatment and the reader would be hard pressed to tell from this book which branch of pharmacology formed the author's main interest. The book is more than an 'Introduction to Pharmacology'. It is not only a suitable text-book for the student, but also a valuable reference book for the pharmacologist who requires brief but thorough information about those branches with which he is less familiar.—R. SCHNEIDER.

Laboratory Handbook of Toxic Agents, edited by C. G. Gray. London: Royal Institute of Chemistry. 1960. pp. 170 + viii. 20s.

The Royal Institute of Chemistry is to be congratulated on the appearance of this handbook, for which there is so much need. Not only is a volume of this type necessary for first aid in the laboratory itself; collaboration is required between the doctor and the chemist and, in the experience of your reviewer, when a patient is passed from a laboratory to a hospital or a doctor, the tendency is to enquire about the treatment already given and to continue with it. On occasion, hospitals will telephone laboratories for advice regarding the treatment which should be given to patients who have been admitted and are believed to be suffering from certain types of poisoning. While, therefore, a chemist can be expected only to remember how to deal with common types of accidents likely to occur in his own laboratory, it is very useful to have at one's command a book of ready reference from which to gather advice to pass to others. In the case of laboratory accidents the speed and accuracy of the initial treatment is generally more than half the battle and two instances of incorrect treatment in the first instance causing later trouble come to one's mind. In the first of these the patient spilled a bottle of bromine down his body, and after treatment in the laboratory with saturated sodium bicarbonate solution, this treatment was continued at one of the large teaching hospitals. In the second case a man laid out with phosgene was treated with amyl nitrite to revive him.

No one is better qualified than Prof. Gray to edit a volume of this type and he has drawn into service Sir Roy Cameron to write the introduction and describe general principles; Messrs. E. N. Dodd and J. S. Beard to write on precautions and preventions; Messrs. G. D. Muir and W. G. Moss to write on first aid in the laboratory and, in collaboration with Dr. Ethel Browning, on poisonous and corrosive gases, reagents and solvents; and Messrs. A. Quinton and V. A. Broadhurst to write on precautions against radiations.

Earlier efforts have been made to write booklets on laboratory precautions but the reviewer has seen nothing as ambitious as the present volume and certainly nothing approaching its utility. If, therefore, one or two comments are made it is hoped that they will merely be useful for consideration in future editions and not construed as criticisms. In the reviewer's experience it is very seldom that poisons are really swallowed in the laboratory due to the use of pipettes and similar apparatus. While an assistant or student is generally too nervous to form an estimate for himself his senior should endeavour to make a rapid appraisal of the situation. Older chemists will remember how as

young students they invariably got saturated potash solution into their mouths using a Hempel gas apparatus, yet none really passed down the throat, and a cautionary word of warning on this point would be useful. If an assistant really swallowed sodium sulphide the giving of an emetic would appear to be about the least of several evils and it may, perhaps, be suggested that the addition of a little ferrous sulphate to such an emetic would be useful. For bromine on the skin the reviewer would suggest the alternative, sodium thiosulphate, rather than ammonia, if the bromine which has been absorbed into the skin is to be inactivated immediately and not left to corrode. And lastly some guide as to the quantity of a poison or irritant taken internally likely to be dangerous would be a most useful guide not only for use in cases of accidents in the laboratory, but as a help for general forensic work. This information is seldom available and often contradictory.—THOMAS MCLACHLAN.

Sterilization in Food Technology, by C. Olin Ball and F. C. W. Olson. 1st Edition. New York: McGraw-Hill Book Co. pp. 654. $16.00.

This book is a classic. The sterilization process was first studied mathematically in 1920, and the development of the analytical theory towards its present important position has been very largely guided by C. Olin Ball. Many other workers have added their own contributions, for example Olson who is Ball's co-author in this book, Stumbo, Gillespy and Hicks, but we are sure that they would all unhesitatingly give pride of place to Ball. This book is a compilation of the theory which has been built up over 40 years, and there is no other book which even pretends to cover the same field.

A classic, indeed, but like many classics it is long, diffusely written, and at times so involved as to be unreadable, even in the non-mathematical parts. However, criticism of a scientific work, unlike some criticism of general literature, can only be valid in two circumstances: either if the critic is satisfied that the work is incorrect, or if he is satisfied that he could have done better than the actual workers or writers, working at the same time and with the same body of information. It would be a brave man who would take up the second position, and certainly we do not presume to do so. Criticisms of the book must therefore be judged in this light.

Many topics are covered. For example, about 100 pages are devoted to a comprehensive survey of the practice of sterilization, to the desirable operating conditions for stationary autoclaves, and to more recent developments in processing plants. The so-called 'high-short' methods are discussed, together with some aseptic filling systems which have been used with the high-short processes. These include that ultimate in systems, the Smith-Ball process, in which all the filling and sealing operations take place within a pressurized room maintained at an air pressure of 20 lb./in.^{2} so that aqueous liquids open to the room atmosphere have a boiling temperature of about 260°F. The operators enter and leave the operating chamber through air locks, allowing time for decompression on leaving.

A simple introduction to bacteriology is followed by a discussion of thermal death curves. Only semilogarithmic thermal death curves are considered, and the authors suggest that any thermal death curves which are not semilogarithmic are probably incorrect because time lags in heat penetration have not been considered. We feel that this is too simple a conclusion, and it must now be accepted that some organisms do not show a semilogarithmic order of death. The straight line relationship seems to be a convenient special case which is fortunately widely applicable. The presence of non-linearity introduces a complication into the theory and calculations, but it should be accepted as otherwise there may be severe errors at low proportions of survivors.

A large section of the book deals with the principles of heat transfer which govern the shapes of the time-temperature curves which are likely to be encountered in practice. Conduction heating, convection heating, and combinations of the two are considered.

Finally, about half of the book is devoted to different methods of process calculation, starting with the simpler general methods and proceeding to the extremely complex formulae which are derived from the equations of heat penetration and of thermal death. Values of the mathematical functions which arise in these calculations are tabulated, and nomograms are given for the solution of some of the problems. Only a specialist will be able to follow this part of the book. There is a further chapter in which the same principles are applied to the effects of heat treatment on the organoleptic and nutritional properties of foods.

The number of symbols required in these calculations is formidable, and many of them seem to have been rather arbitrarily chosen. This is probably a reflection of the fact that this body of theory has grown up from a much simpler set of original ideas, and the symbols used at first have been extended to deal with more involved problems. If at some stage the symbols had been reconsidered it might have been possible to simplify them to make the subject more understandable to newcomers.

At various points in the book, there is some rather discursive philosophy which might have been cut down, for example on the question of the criterion of sufficiency of a sterilizing process. Whatever the mechanism of the effect of heat on spores is supposed to be, this subject is made to appear unnecessarily difficult.

These criticisms are not criticisms of the work but of the way in which it is presented. A subject of this kind, which deserves to be more widely understood, needs to be made easy to attract new adherents. It may be that a book as comprehensive as this one is could never be made easy. If so, this is a definitive text for the few; perhaps the authors, or some others of the few, might consider a distillation of the material to produce something in the nature of a 'Beginners' Guide'.—H. BURTON.

MAGNETOCHEMISTRY

by A. Earnshaw, Ph.D.

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PART III—THE CONSTRUCTION OF A TEMPERATURE VARIABLE GOUY BALANCE

IT IS now widely accepted that in any serious magnetochemical investigation temperature dependence studies are essential. These are necessary not only to show the existence, but also to measure the magnitude of departures from ideality. For this purpose the region of most interest is below room temperature, and this article deals with the construction of a magnetic balance suitable for measuring susceptibilities from room temperature (or above) down to temperatures approaching that of liquid nitrogen.

The principle is precisely the same as for single temperature measurements, the balance being of the same type as described in the previous article. Here, however, the specimen has to be surrounded by a fairly bulky cryostat by means of which the temperature can be controlled. In order to obtain field strengths of a sufficiently high value, with the wide pole gap that the cryostat entails, an electromagnet is essential. This has the additional advantage over a permanent magnet that it allows measurements to be made at a variety of field strengths so that ferromagnetic impurities can be detected*. Fig. 3 illustrates the apparatus.

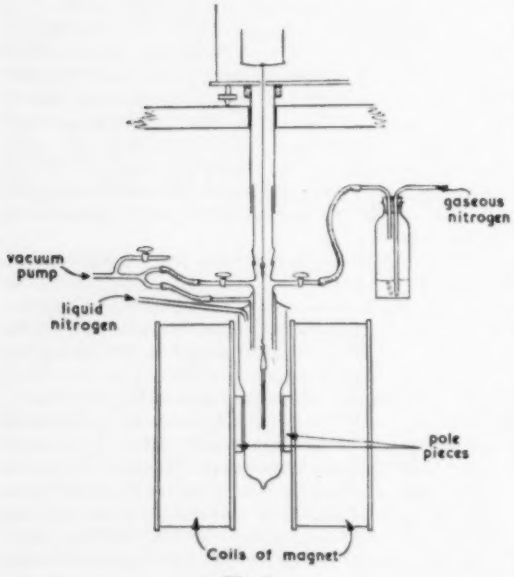

Fig. 3.

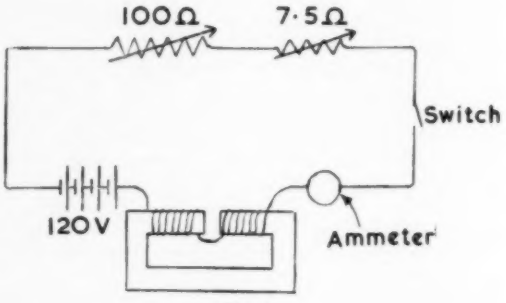

Fig. 4.

Magnet

The Humphrey's Sucksmith type electromagnet meets the requirements, providing a field of nearly 8,000 oersteds with 10 cm. diameter pole pieces, a pole gap of 6 cm. and a current of 10 amp. It is possible to use rectified mains as the current supply but to obtain the necessary constancy in voltage is frequently a costly business by this method. In the author's experience nickel-iron batteries provide the most satisfactory source having the advantage over lead accumulators of being more robust and requiring less attention. The current is measured by means of a good, mirror scale ammeter. It is not necessary to have a high absolute accuracy in measuring the current but the reproducibility must be good.

In order to vary the current two variable resistances are included in the circuit (Fig. 4), one for coarse adjustment and the other for fine adjustment. For the Humphrey's magnet convenient rheostats are a 100 ohm stud type and a 7·5 ohm sliding contact type along with a 120 volt Nife cell supply, and an ammeter with a full scale deflection of not more than 15 amp. By this means currents up to 12 or 13 amp. can be used though in practice 10 amp. are usually sufficient.

Cryostat

In order to take satisfactory readings with the specimen at a predetermined but variable temperature four things are necessary.

(i) a method for cooling the system
(ii) a method for heating the system

*While diamagnetic and normal paramagnetic susceptibilities are independent of the strength of the applied field, this is not so for ferromagnetic susceptibilities. Thus field variation affords a simple method for detecting ferromagnetic impurities.

(iii) a thermostatic arrangement to ensure that (i) and (ii) balance

(iv) a means of measuring the temperature.

The cryostat itself incorporates (i) and (ii) and is illustrated in Fig. 5. It is essentially the same as that described by Figgis and Nyholm[1]. Liquid nitrogen is the coolant. The specimen is suspended inside a copper chamber which is heated electrically and the heat losses from the copper to the liquid nitrogen are reduced by interposing a variable vacuum between them. But to consider this in greater detail:

(i) The coolant is contained in the 'outer dewar' which is about 12 in. long and is tapered to fit in a 6 cm. pole gap. The dewar is clamped permanently in position between the pole pieces of the magnet. The level of the coolant is maintained automatically by a method illustrated in Fig. 6. The coolant is forced into the dewar by compressed air from a quarter horsepower compressor. This is operated by a Sunvic relay type F.102/3M in conjunction with a thermistor of room temperature resistance 4,000 ohms which is situated just inside the top of the dewar. Thus when the level of the coolant falls too low the resistance of the thermistor decreases sufficiently to cause the relay switch to close and so start the compressor which forces more coolant into the dewar from the reservoir. As the level of coolant rises the resistance of the thermistor increases, the switch opens and the compressor is turned off. A small leak in the compressed air line allows the excess pressure in the reservoir to be released. By this means the level of liquid nitrogen coolant is maintained in the dewar as long as the reservoir contains an adequate supply.

The consumption of liquid nitrogen varies between about 500 ml. and 750 ml. per hour depending on the temperature of operation.

(ii) Heat is supplied by a 35 ohm nichrome coil wound around the copper chamber and through which currents of up to 1 amp can be passed. The copper chamber is 7 in. long with an outer diameter of $\frac{7}{8}$ in. and a $\frac{3}{8}$ in. diameter hole bored off centre to allow for the fine hole which accommodates the thermocouple. The copper is threaded on the outside to facilitate the winding of the heating coil (and also the platinum resistance mentioned below), the leads of which are connected to terminals insulated at the top of the copper by mica, all junctions being silver soldered. A two start thread of two turns per inch is most suitable. The leads are insulated by glass fibre sheaths soaked in Araldite and baked.

The inner dewar separating the copper chamber and specimen from the liquid nitrogen is just wide enough to accommodate the chamber, and the double walled section, which may be silvered, extends just above the top of the outer dewar. An Edwards Speedivac model 2S50 high-vacuum pump produces the vacuum. The neck of the dewar terminates in a B.29 ground glass joint below which are four side arms at right angles. Two of these are fitted with ground glass vacuum taps which act respectively as an inlet for gaseous nitrogen

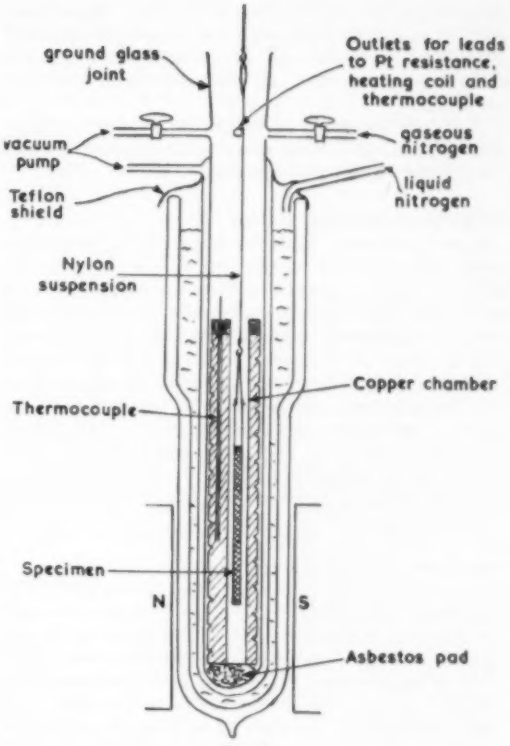

Fig. 5.

and as a connection to the vacuum pump. The other two outlets are for the electrical leads from the copper chamber and must be carefully sealed with picein.

The inner dewar is clamped firmly in position, care being taken that the chamber in which the specimen hangs is perfectly vertical. To prevent ice condensing into the liquid nitrogen a shield of Teflon is taped between the two dewars.

Thermostatic Control

An adequate temperature controller can be made to the design of Roberts[4] by substituting a 15 ohms resistance for the 32 ohms resistance which he designates as R_2. It is essentially a bridge system, one arm of which is a platinum resistance and the other a variable resistance.

The platinum is 0·005 in. diameter wire and is wound round the copper chamber with the heating coil, from which it is insulated in the manner described above. If the wire is wound down one thread on the copper and up the other about 7 ft. are required giving a room temperature resistance of about 20 ohms.

With the variable resistance appropriately set the liquid nitrogen causes the system to cool and the resistance of the platinum falls, putting the bridge out of balance. The out-of-balance voltage is used to operate a relay which switches on the heating current and

restores the balance. Heating is therefore intermittent but, because of the heat capacity of the copper chamber, this effect is 'smoothed out' and the specimen suspended in the middle attains an effectively constant temperature.

The instrument can be calibrated, and by correctly setting the variable resistance any temperature between 80 and 400° K can be maintained.

Measurement of Temperature

The temperature is measured accurately by means of a nichrome-constantin thermocouple. The 'hot' junction is spot welded and the 'cold' junctions silver soldered to copper leads and immersed in an ice-water bath. The e.m.f. is measured on a Tinsley potentiometer type 3387B which can be read to within ± 0·000005 volts.

The nichrome-constantin junction is placed in a narrow hole, drilled for the purpose, half way down the wall of the copper chamber and the temperature so measured is taken as that of the specimen itself. This can easily be checked but is in fact a justifiable assumption provided that sufficient time is allowed for thermal equilibration.

Specimen and Suspension

The specimen is finely powdered and packed into a tube somewhat longer (say 12 cm.) than that used for single temperature measurements with a permanent magnet and in this case a Perspex tube is preferable to glass. This is because glass, though it is diamagnetic, contains a small amount of ferromagnetic material which causes the correction for the tube to vary with temperature. Consequently if glass is used the tube must first be calibrated over the whole temperature range. Perspex, which is purely diamagnetic and has a correction independent of temperature, obviates this need and is obviously preferable to glass unless the chemical nature of the specimen makes it unsuitable. Nor is it feasible to use an aluminium collar as was done previously, simply because of lack of space in the copper chamber.

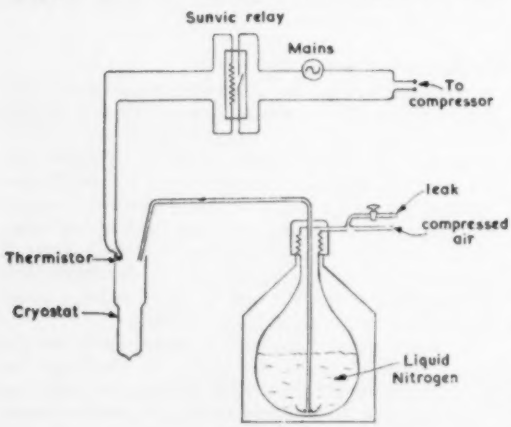

Fig. 6.

A convenient method of suspension which involves no increase in diameter is to bore two small holes horizontally in the top of the Perspex tube diametrically opposite each other. A loop of springy wire suitably bent will clip in the holes and allow the tube to be hooked to the nylon suspension from the balance pan. Alternatively if glass is used, or if the specimen must be sealed, a loop of very thin nylon thread can be secured by a small rubber stopper in the top of the tube.

As the cryostat's position is fixed it is necessary to introduce the specimen from the top without moving the cryostat. In order to facilitate this the glass column which encases the suspension is made of two concentric tubes fitting loosely together. The upper, wider tube fits flush with the balance case and is fixed permanently in position. The lower, narrower tube with a B.29 ground glass joint which fits into the neck of the inner dewar of the cryostat, can then be raised to allow the specimen to be attached to the hook on the suspension and lowered into the cryostat.

It should be noted that if measurements are to be made below 90° K they cannot be performed with an atmosphere of air, because paramagnetic oxygen would then condense on to the specimen. Nitrogen is the most convenient atmosphere in the present case and has the additional advantage over air that it is not necessary to measure the volume of the specimen tube because the equation

$$\chi = \frac{2wgl}{WH2}$$

is applicable.

Before inserting the specimen the inside of the inner dewar is first evacuated by placing a rubber bung into the top and connecting the appropriate side arm to the vacuum pump. If the tap on this side arm is then closed, oxygen-free nitrogen can be allowed in from the other side arm. Two or three repetitions are sufficient to ensure an atmosphere entirely of nitrogen which can be maintained by continuing to pass a slow stream of nitrogen throughout the experiment. This escapes up the glass column and prevents atmospheric oxygen diffusing back into the cryostat.

If the nitrogen is first dried by passing through a sulphuric acid bubbler the rate of flow is thereby indicated. A bubble per second is an adequate rate and has no detectable effect on the weighings.

Field Calibration

Determinations of field strengths and the minimum length of sample required are carried out as for the permanent magnet. The only differences are that in this case a greater length of specimen is required (probably about 10 cm.) and the determination of field strength should be repeated for a range of difference magnet currents. If Perspex tubes are used some difficulty is experienced using $Hg[Co(CNS)_4]$ as this tends to stick to the walls of the tube. For this reason nickel chloride solutions are probably more satisfactory.

Thermocouple Calibration

Use is made of the results of Haas and Gorter[2] who determined the susceptibility of copper sulphate pentahydrate from room temperature to the temperature of liquid helium, their results being later confirmed by Reekie[3]. Over the range of temperature of interest here (room to liquid nitrogen) copper sulphate pentahydrate was found to obey the Curie-Weiss Law with $\theta = 0{\cdot}7°$.

A tube is packed, as already described, with the finely powdered calibrant and the pull measured at 5° intervals from room temperature to the lowest temperature obtainable, noting the potentiometer reading in each case. If one of these temperatures can be accurately established all the others can be calculated. The most convenient is 0°C. at which the potentiometer must give a zero reading. As it is difficult to arrange to make a reading at exactly this temperature a graph of pull against thermocouple e.m.f. is drawn from the points in its neighbourhood. This is virtually linear and so the pull at exactly 0°C. can be read off. The gram susceptibility of the calibrant at 0°C. is $6{\cdot}74 \times 10^{-6}$ from which H can be calculated. From this it is possible to calculate χ at all the other temperatures. By adding the diamagnetic correction, $0{\cdot}4 \times 10^{-6}$, and multiplying by the molecular weight, χ_A is obtained and the Curie-Weiss Law applied.

$$\frac{\chi^\circ_A}{\chi_A} = \frac{(T + 0{\cdot}7)}{273{\cdot}9}$$

Where χ°_A is the atomic susceptibility obtained from this equation.

It should be noted that the temperature calibration is not subject to the packing errors to which a field calibration would be subject, because in this method the accurate field strength (as determined by $NiCl_2$ solution) is not used. Instead an effective field strength calculated from the pull at 0°C. eliminates packing errors.

For temperatures above room hydrated copper sulphate is of no use because of the loss of the water of hydration, so that for the higher temperatures a direct calibration against a good mercury thermometer is necessary.

By plotting thermocouple e.m.f. against temperature it is subsequently possible to estimate a given temperature from this graph to within 0·1° at the higher temperatures though, due to the changed slope of the curve, this is probably 0·2° for the lower temperatures. This accuracy is quite adequate for all normal work.

Experimental Procedure

After flushing the chamber with nitrogen the specimen, finely powdered and packed into the tube, is hooked on to the suspension and lowered into the chamber. It is then weighed with and without the field, extracted, repacked and remeasured to ensure constancy of packing. When this is satisfactory the sample is placed in position, the temperature control is set at room temperature and, with the vacuum applied between the walls of the inner dewar, the liquid nitrogen supply switched on. Once the thermostat has begun to function, half an hour is sufficient for equilibrium to be attained and then weighings with and without the field are repeated for at least three different field strengths. If these readings give closely similar values for the susceptibility of the specimen then the absence of ferromagnetic impurities can be assumed and measurements continued.

With the thermostatic control set at a lower temperature the vacuum on the inner dewar can be released to allow more rapid cooling. When the required temperature is reached the heating current is automatically switched on and the vacuum should be re-applied. An hour should be allowed for complete equilibrium to be attained.

For temperatures below about 140°K the vacuum can be dispensed with altogether. For temperatures above about 300°K the coolant is unnecessary.

The results are usually presented in the form of a graph of reciprocal susceptibility against temperature which, if the Curie-Weiss Law is obeyed, will be a straight line intersecting the temperature axis at $-\theta°$.

Accuracy

The main source of error in terms of absolute accuracy arises from the packing which cannot be expected to be better than 1 per cent and is often worse, depending on how easily the substance packs. However the self-consistency of the measurements for a given packing can usually be appreciably better. For a typical case in which the pull is of the order of 10 mg. for a magnet current of 10 amp. the weighing errors are less than 0·4 per cent and the field can be controlled to within about 0·1 per cent. If the temperature is measured to within 0·2° this error is not more than 0·2 per cent and is less for the higher temperatures.

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Bisra Open Days

The British Iron and Steel Research Association will hold two 'Open Days' at its Sheffield Laboratories on Thursday and Friday, June 15 and 16, 1961.

The last occasion when the Hoyle Street group of laboratories held 'open house' for representatives of member firms was in 1956. This year's function will therefore give visitors the opportunity of examining the many developments which have taken place since then.

Among the many displays and demonstrations planned by Steelmaking Division will be the latest developments in continuous casting, and work on spray refining and rapid desulphurization. One of the Mechanical Working Division's projects on show will be a recently developed rapid annealing system. Prominent among the Metallurgy Division's projects will be aspects of its general preoccupation with the purification of steel (jet de-gassing, vacuum casting, etc.), work on improved speed and accuracy in analysis, and the production of high-temperature steels.

ELECTRONICS FOR BIOLOGISTS

by G. C. Ware

Department of Bacteriology, University of Bristol

PART IV

The Valve Amplifier

In electronics it is frequently necessary to increase or amplify a small voltage in order either to be able to measure it or to make it perform some useful function. Valves are used for this purpose.

Many people are inclined to drop out of a discussion at the mention of valves but in spite of the enormous number of different types of valves available, and the complex names sometimes given to them, valve operation is fundamentally simple. It is also true that for many operations, any of a large number of different valves will be suitable.

Valves are devices capable of regulating the flow of electricity in the same way as mechanical valves can control fluid flow. Every valve is constructed of several electrodes sealed in a glass or metal envelope and for operation requires sources of electric power to maintain each electrode at its correct voltage. The various electrodes are named according to their function and in circuit diagrams symbols are employed to represent the various electrodes. (Fig. 22.)

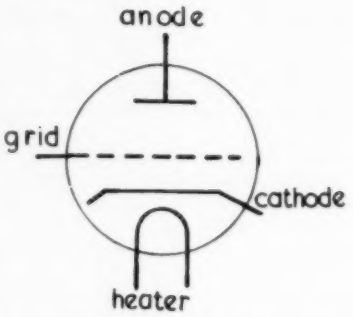
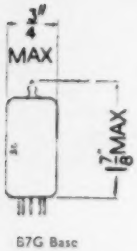


Fig. 22. Diagrammatic representation of an indirectly heated triode valve. In a directly heated valve the cathode is omitted and the heater serves both purposes.

For every valve a *data sheet* is available from the manufacturers, giving the correct voltages to be applied to each electrode. A typical data sheet, for a simple triode (3 electrode valve) is reproduced in Table III. It gives information on the size and shape of the valve, (top left hand diagram) together with the type of base and therefore the type of holder required. There are many types of base, some obsolescent, but only three need be of concern here, namely the B7G base which provides adequate mounting and a maximum of seven connections for small 'all-glass' valves. For more complex miniature valves nine connections are provided by the B9A base. Many larger and heavier valves use the octal base with eight stouter pins to provide adequate support and current carrying capacity. The bases are arranged to allow only one possible position of insertion into the base and thus ensure correct connections. An additional electrode connection is sometimes provided as a metal top-cap to the valve.

On the diagram showing the internal arrangement of the valve (data sheet top right) the pins are numbered 1-7 as seen from the underside of the valve with, for added clarity, a letter designating the name of the electrode to which the pin is connected. Beneath the Type Number, and class of the valve, in this case a miniature high frequency power triode Type 6C4, a brief description of its uses and limitations may follow. The rest of the data sheet is occupied with performance details, ratings, etc.

TABLE III

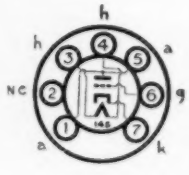


TYPE 6C4

MINIATURE

H.F. POWER

TRIODE



As oscillator or power amplifier, type 6C4 will operate efficiently at frequencies up to 150 Mc/s.

RATINGS	
Heater Voltage	6.3 volts
Heater Current	0.15 amp.
Anode Voltage	300 volts max.
Anode Current	25 mA max.
Anode Dissipation	3.5 watts max.
Grid Current	8.0 mA max.

Class A — OPERATING CHARACTERISTICS			
Anode Voltage	100	250	volts
Anode Current	11.8	10.5	mA
Grid Voltage	0	−8.5	volts
Anode Impedance	6,250	7,700	ohms
Mutual Conductance	3.1	2.2	mA/V
Amplification Factor	19	17	

Part of the manufacturer's data sheet for Type 6C4. (*By courtesy of Standard Telephones & Cables Ltd.*).

For operation most valves require that the cathode should be hot. The operating temperature is usually around 600°C. Any means may be employed to heat the cathode but the simplest method is to construct the cathode as a length of wire and then pass a suitable electric current through it. Such cathodes are termed *directly heated*. Direct heating implies an electrical connection between the cathode and the apparatus providing the heating current. This is usually not permissible so the cathode is constructed near, and often around, but electrically isolated from, a small heater, to provide *indirect heating*. In either type when the correct voltage is applied the cathode can be seen glowing red hot. The data sheet quotes 6·3 V., a very common heater voltage, for the 6C4 and shows the valve to be indirectly heated, the heater being connected to pins 3 and 4 and the cathode to pin 7. The current consumption of the heater is 0·15 A. from which the heater can be deduced to have an effective resistance of 42 Ω when at its working temperature. In common with other metal resistance devices the resistance will be less when the apparatus is cold. To avoid introducing voltage variation in the cathode a directly heated valve requires smooth direct current from an accumulator to heat it but the heater of an indirectly heated valve may be heated with alternating current. A simple transformer, providing 6·3 V. and capable of delivering sufficient current, or even a resistor is all that is necessary.

When designing a circuit it is convenient to select all the valves to have the same heater voltage so that they may be run from the same supply (Fig. 23a). It is desirable to earth the heater circuit to ensure that the heater cannot accumulate a charge with respect to the other electrodes of the valve. Any *one* point in the circuit may be earthed. Heater connections are almost invariably identical in all circuits and details are therefore often omitted from circuit diagrams; the transformer and heater connections being either marked

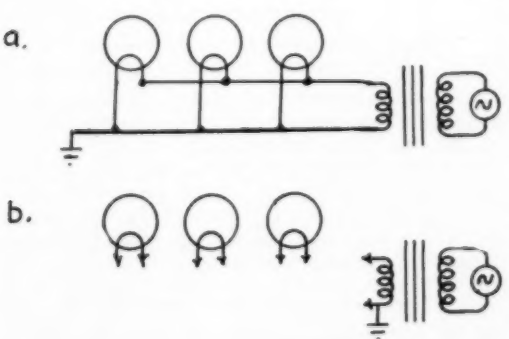


Fig. 23. (*a*) **Heating circuit for a number of indirectly heated valves connected in parallel to a transformer.** (*b*) **To avoid confusion on circuit diagrams the heater connections are often not shown in detail and may even be completely omitted.**

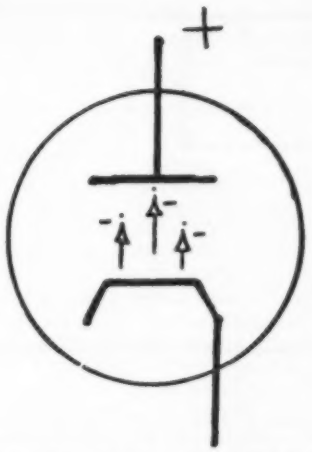


Fig. 24. When hot the cathode emits electrons which will be attracted to a positive anode. This constitutes the main, and normally the only, flow of current through a triode.

with a common symbol (Fig. 23b) or omitted altogether. It is also common practice in circuit diagrams to omit for clarity sections not directly under consideration.

Anode Circuit

When the cathode is hot it emits electrons which can transverse the space between cathode and anode provided a suitable potential difference exists (Fig. 24). As electrons are negatively charged the anode should be made positive to attract them. The anode is cold and emits no electrons so flow in the reverse direction is not possible. The current flowing in at the cathode is therefore always equal to the current flowing out at the anode. The data sheet suggests two alternative anode voltages for the 6C4 each of which require corresponding voltages for the other electrodes but any high positive voltage below the permitted maximum, shown under ratings, will be suitable provided that the other electrode voltages are adjusted. If an alternating voltage is applied between anode and cathode the valve will act as a half wave rectifier, current being able to flow only from cathode to anode. In practice valve rectifiers are more common than metal junction types.

The space between the cathode and the anode acts as a variable resistor; by changing the voltage of the grid the resistance of this space, and therefore the current flowing from cathode to anode, may be varied. Small variations of grid voltage can produce large changes in anode current. If an external resistance is included in the anode circuit, known as the *Anode Load Resistor* (Ra Fig. 25), then as the current through the valve and resistor varies so also will the voltage drop across the resistor and therefore also across the valve ($I = \frac{E}{R}$). If

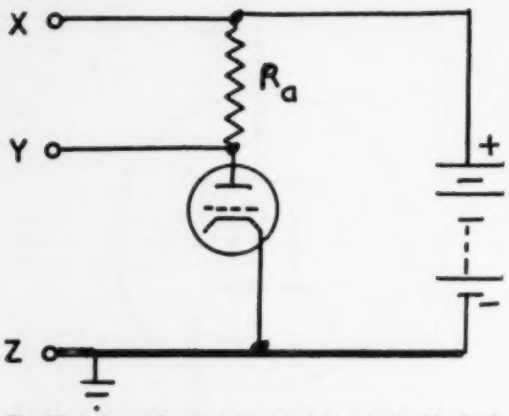


Fig. 25. A change in the resistance of the valve in this circuit will alter the current flowing and produce a voltage change between X and Y and Y and Z. Either of these voltages, but more usually YZ, may be used as the output.

this variation of voltage is greater than the change of grid voltage which produced it the valve is said to *amplify*; if it is less the circuit is *degenerative* and *attenuation* has occurred in place of amplification. Obviously, the higher the resistance of the anode load resistor the greater will be the voltage change for a given current change and therefore the greater the amplification of the circuit. In practice the useful limit is reached for a triode when the anode load is about five times the anode impedance of the valve (see Table III).

Grid Circuit

It is necessary also to provide the correct grid voltages. Since all electrode voltages on the data sheet except the heater voltage are measured between the electrode in question and cathode, a grid voltage of 0 V., specified for the 6C4 where the anode voltage is 100 V., is easily obtained by directly connecting the grid to

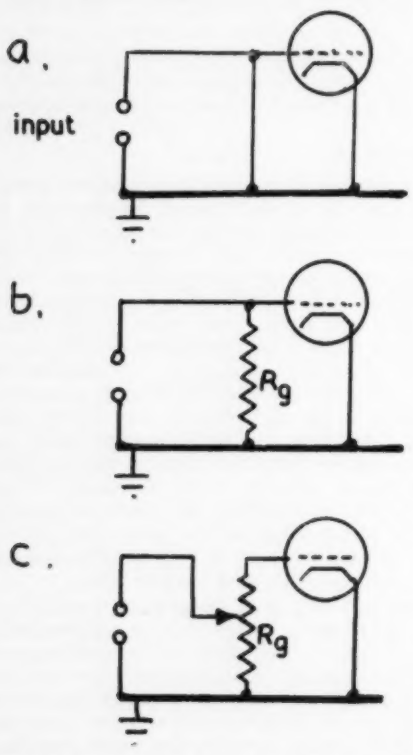


Fig. 26. (*a*) Maintenance of the grid at zero volts by a direct connection to earth will result in a short circuited input. (*b*) A high resistance (about 1 M.Ω) will connect the grid to earth and yet avoid excessive loss of the signal to earth. (*c*) By controlling the amount of signal directed to earth the amount of signal applied to the grid may be controlled.

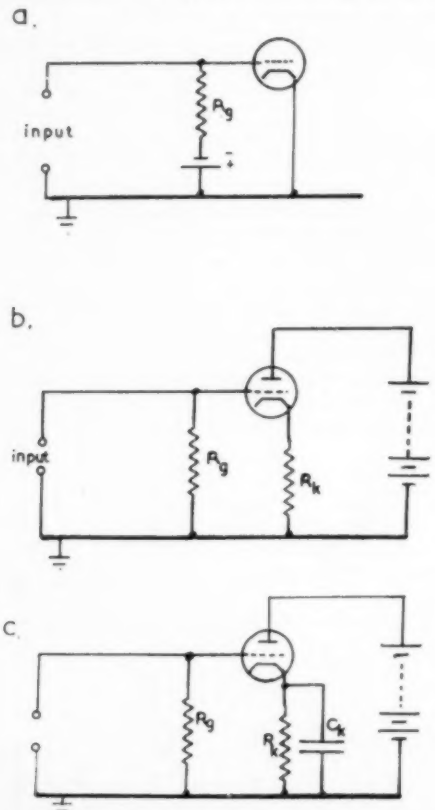


Fig. 27. The grid voltage may be provided (*a*) by a battery in the grid circuit or (*b*) by cathode bias, the cathode being made positive with respect to the grid by insertion of a cathode resistor. (*c*) A capacitor (C_k) is then necessary to allow the signal current to by-pass the cathode resistor and prevent variations in grid voltage.

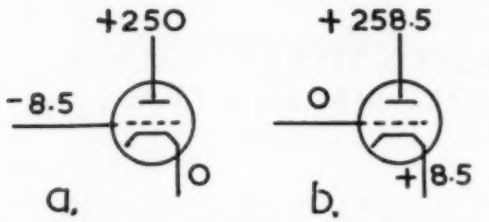


Fig. 28. A negative grid voltage, with respect to cathode (*a*) may be translated into a positive cathode voltage with respect to the grid (*b*). The theoretical increase in the anode volts to maintain the anode voltage with respect to cathode is not required in practice.

cathode (Fig. 26a). However, the incoming voltage which it is required to amplify, known as the *signal*, is also applied to the grid, and its connection to the cathode results in a short circuited input. A resistor whose resistance is large enough (about 1 M. Ω) to avoid serious loss of the input signal is therefore used to connect the grid to cathode Fig. 26b. By definition no current flows from the grid of a class A amplifier, that is a voltage amplifier such as we are discussing, so the voltage drop across the grid resistor Rg is zero ($I = \frac{E}{R}$). and the grid is at the same potential as cathode just as though connected directly instead of through a high resistance. By making the grid resistor Rg variable, it is possible without disturbing the grid voltage to divert more or less of the input signal to earth and thus reduce the signal voltage applied to the grid and therefore the output. This is a very common method of amplification control. (Fig. 26c.)

Negative grid voltages, as required for instance by the 6C4 at high anode volts (see Table III), can be obtained from batteries (Fig. 27a), which have an exceedingly long life in the grid circuit since no current is drawn, or by separate power supplies, or by what is known as autobias or cathode bias.

Cathode Circuit

As electrode voltages are measured from the cathode, a negative grid voltage, implying the grid being more negative than the cathode which is at zero volts, is identical with the cathode being positive with respect to the grid at zero volts. Current is flowing in the cathode circuit, but not in the grid circuit, so insertion of a resistor Rk in the cathode connection will cause a rise in the cathode voltage but the grid voltage will remain at zero being connected to earth by Rg (Fig. 27b.) The corresponding change which occurs in the anode voltage, measured to cathode, is small and can be neglected.

In the case of the 6C4 when the anode voltage is 250 V. the required grid voltage is – 8·5 V. and the anode current is 10·5 mA. The corresponding voltages with the grid at zero would be + 8·5 V. at the cathode and + 258·5 V. at the anode (Figs. 28a & b). To obtain a voltage drop of 8·5 V. the cathode resistor must have a resistance of 810 Ω. ($I = \frac{E}{R}$). The nearest preferred value of 820 Ω would be suitable.

We have seen that the anode current varies in response to the input signal at the grid. The cathode current, which is the same as the anode current, is not a steady current, so the voltage developed across the cathode resistor Rk will not be a steady voltage. This means that the grid voltage varies also which is undesirable as it confuses the incoming signal voltage at the grid. The unwanted variation of the cathode voltage may be removed by connecting a large capacitor, often an electrolytic type of 50 μF. or more, between cathode and earth (Fig. 27c). The effect of this capacitor is to allow the varying signal current to by-pass the cathode resistor whilst causing the steady cathode current to pass through it and generate a steady grid voltage. The capacitor need only be a low voltage type because neither the signal voltage nor the steady cathode voltage will be high. Fig. 29 shows the complete amplifier.

The grid voltage is the only valve voltage (other than the heater voltage) which is critical and great care should be taken to ensure that it is correct. Valves may be seriously damaged if operated with their grids at wrong voltages or not connected at all. With a suitable meter the grid voltage may be checked directly by measuring the voltage of the cathode above earth but for reasons discussed earlier unless the meter is of very high resistance, the cathode *current* should be measured and the voltage drop in the cathode resistor calculated.

(To be continued)

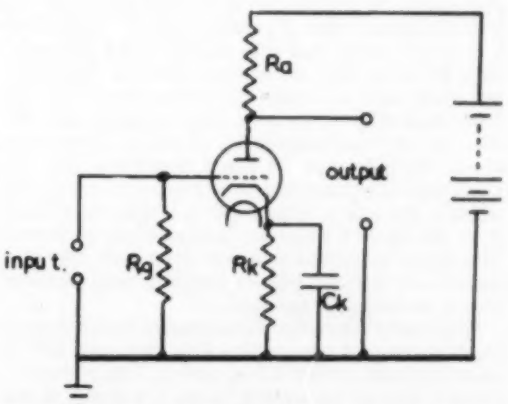


Fig. 29. Complete circuit of a triode voltage amplifier. Ra should be about 20 K.Ω, Rg about 1 M.Ω, and Ck 50 μF. to insure low frequency amplification. For value of Rk see text.

TWO ELECTRICALLY-OPERATED TITRANT VALVES

by John T. Stock, M.Sc., Ph.D., F.R.I.C., and M. A. Fill, F.R.I.C.*

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ELECTRICALLY-operated burette or titrant valves fall into four main classes (Stock, 1958). Valves in which compression of a flexible tube controls the flow of titrant are often simple to construct, rarely subject to leakage, and easy to service. Two valves of this class have been developed. Both are designed to operate on a 4 to 6 volt d.c. supply and have built-in controls for wide adjustment of the rate of titrant delivery. In addition, the response of the second of the valves is designedly quite sensitive to the operating voltage, so that remote control of the flow rate is possible.

The lever-type valve unit shown in Fig. 1 is a slight modification of the one demonstrated in Birmingham during the 1958 International Congress on Microchemistry. The unit is assembled within two 95 mm. diameter plastic reagent-bottle caps that are mounted mouth-to-mouth. As the parts are mounted on the rear cap, as shown, the front cap serves merely as a cover, is retained by two bolts that pass through holes AA, and may be readily removed for adjustment purposes. Projecting at right angles from the back and secured by woodscrew B, a 5 in. length of $\frac{1}{2}$ in. diameter hardwood rod enables the unit to be supported in a screw clamp on a burette stand.

Passing through a small hole in the rear cap, a length of cycle valve rubber tubing C carries the titrant solution into the unit. This tubing passes between two pairs of small pins that are driven into hardwood pressure block D and then curves round to join glass tubing jet E. Supported in two small 'Terry' clips, the jet may be easily snapped in and out of position. The pins locate the rubber tubing at right angles to the lower, rounded, edge of pressure lever F, which is of $\frac{1}{2}$ in $\times \frac{1}{8}$ in. mild steel strip and is twisted as shown. Held by brass bolt H, small rectangular sheet lead plates are used to obtain the correct loading of the lever. Steel strip of the same cross section is used for the core of electromagnet G, which is wound with about 150 ft. of No. 26 gauge enamelled wire, the extremities being attached to terminals. To retain the winding, the core is backed with a 1/32 in. thick brass strip, the ends of which are bent upwards as shown. The magnet is secured by 6 B.A. brass bolts that pass successively through a brass retaining strip, distance pieces, the back cap, and nuts.

When sufficient current flows through the winding of the electromagnet, the pressure lever rises until bolt H meets the head of brass 6 B.A. screw I. This movement partially relieves the nipping action of the edge of the lever upon tubing C and slow flow of titrant occurs. Screw I carries a $\frac{3}{4}$ in. sleeve of rubber tubing, the bore of which is slightly larger than the crest-of-thread diameter. By rotation of knurled nut J, the screw may be drawn upwards through the plain hole in bracket K, thus compressing the sleeve. This increases the at-rest clearance between H and I, permits greater rise of the pressure lever, and thus increases the rate of flow. The setting of this type of control is insensitive to vibration (Stock and Fill, 1954).

For such purposes as washing out and expulsion of air bubbles, it is convenient to be able to operate the valve by hand. This may be done by partial rotation of a small knob on the back of the unit. The knob is mounted on the shank of a bolt, the large cheese head K of which has a flat filed on one side. When the bolt is rotated from the position shown, the modified head acts as a cam and raises the lever.

A recent development of this type of valve permits it to deliver titrant at two different preselected rates (Stock and Fill, 1960).

In the second form of titrant valve, the electromagnet has a movable core. This permits easy adjustment of the response of the valve to a given applied voltage. Fig. 2 is a cross-sectional view of the unit on a horizontal plane through the axis of the core. Front and back plates are of $\frac{1}{8}$ in. thick plastic or $\frac{1}{16}$ in. thick brass

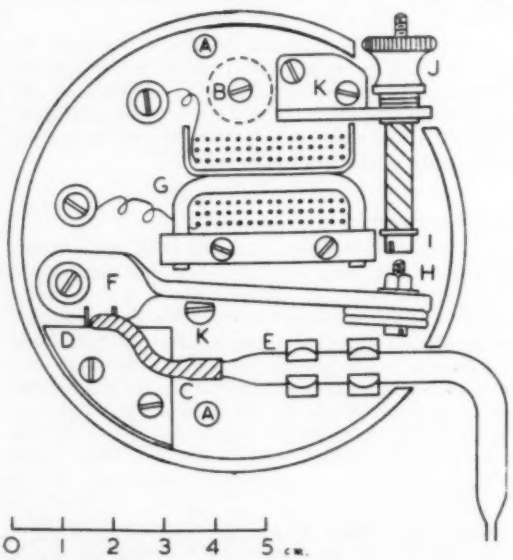

Fig. 1. Lever-type titrant valve.

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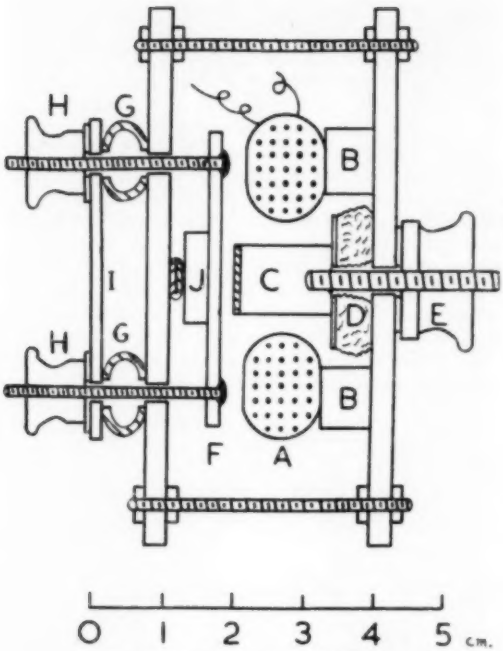

Fig. 2. Movable-core titrant valve.

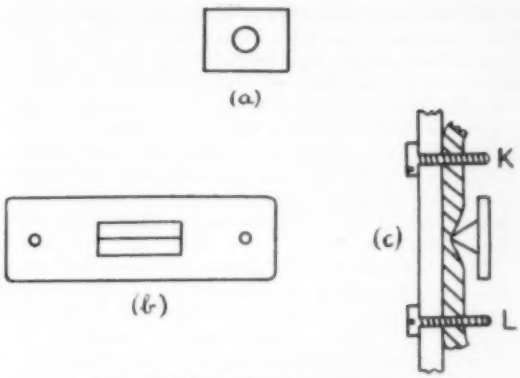

Fig. 3. Details of armature and accessories.

sheet and are 3 in. square. The plates are joined to one another by four pillars, two of which are shown. Each pillar is a 1½ in. length of 6 B.A. brass screw rod with suitable nuts. Two 'Terry' clips mounted in-line on the back plate permit the unit to be snapped directly on to the upright of a burette stand.

Hank-wound solenoid A contains about 150 ft. of No. 26-gauge enamelled wire, the ends of which are joined to terminals (not shown). This solenoid is mounted on two wood or plastic strips BB that act as distance pieces and is secured by small clips (not shown). Mild steel core C is drilled axially for a short distance at one end and a 1 in. length of 4 B.A. brass screw rod is soldered in. The screw rod passes successively through a thin brass washer, sponge rubber disc D, the front plate of the unit, another washer, and finally engages knurled nut E. When this nut is tightened, the clearance between the core and armature F is increased; when E is slackened, the spring action of the sponge rubber diminishes this clearance. A disc of thick paper cemented to the face of the core prevents direct contact between armature and core. This prevents the sticking that might otherwise occur when operating with a small core-to-armature distance.

The armature is of ½ in × $\frac{1}{16}$ in. mild steel strip. Passing squarely through the holes in the armature as shown and secured by drops of solder, two pieces of 6 B.A. brass screw rod act as guides for the armature and transmit to it the retracting force of the 'springs' GG. Shown in plan view at (*a*) in Fig. 3, each 'spring' is a ½ in. length of ⅜ in. outside diameter rubber tubing. Holes 4 mm. in diameter are bored squarely and symmetrically right through the opposing walls of the tubing, so that the 'springs' fit loosely upon the guides. Alternatively, the 'springs' may be left unbored. They are then merely slipped between pressure and back plates and secured by smears of rubber cement applied to the back plate. Rotation of knurled nuts HH alters the position of brass pressure plate I and hence the retracting force applied to the armature. To the underside of the armature is sweated brass wedge J, the

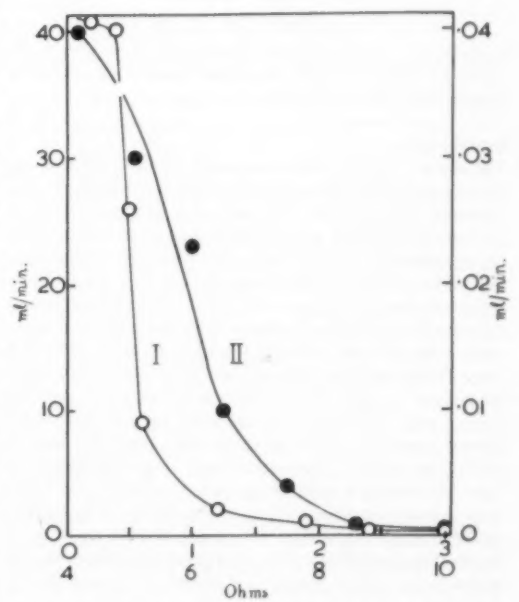

Fig. 4. Variation of rate of flow with external resistance in circuit. Curve I, left hand rate and upper resistance scales; II, right hand and lower scales.

slightly rounded knife edge of which nips against the back plate and cycle valve tubing through which the titrant is conducted. The location and action of the nipping wedge are shown at (*b*) and (*c*) in Fig. 3. Pairs of screws set $\frac{3}{16}$ in. apart at K and L respectively act as guides to locate the valve tubing so that it passes squarely beneath the wedge. A glass jet similar to that shown in Fig. 1 is attached to the lower end of the valve tubing, the other end of which passes through a hole near the top of the backplate and is attached to the titrant supply.

When the solenoid is sufficiently energized, the armature is attracted to the core and the pressure on the valve tubing is partially relieved. Flow of titrant then occurs. For a given applied voltage, the force of attraction, and hence the rate of flow, is diminished by rotation of E to increase the core-to-armature distance. When a suitable setting for E has been selected, the flow rate may be controlled by varying the voltage applied to the solenoid. This may, of course, be achieved quite simply by placing a 10 ohm variable resistor in series with the solenoid and the power supply. The resistor should be capable of carrying a current of at least one ampere. As illustrated in Fig. 4, the rate of titrant delivery can be varied conveniently and quite widely by this method. The pressure head was here maintained close to 75 cm. for all observations.

Such remote and continuously variable control of titrant flow may be of value in automatic potentiometric and other titrimetry. By continuous electronic differentiation of the titration curve during the process, an initially high rate of titration could be smoothly and progressively reduced as the end point is approached. This should allow routine titrimetry to be carried out with the maximum degree of rapidity consistent with minimal and negligible overshoot of end point.

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A Device to Facilitate the Production of Deionized Water

by H. J. Wilson, F.I.M.L.T.

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SUMMARY

A device for facilitating the production of a supply of deionized water with the minimum amount of attention and manual effort is described.

Introduction

'Distilled' water for laboratory use can be obtained by using a deionizer. The principle of this apparatus is the removal of ions from the water by treatment with a mixture of anionic and cationic exchange resins. The water so produced is of very good quality provided that the resins are not exhausted. Using tap water as a supply is disadvantageous because of the large amount of ions present in such water. It is preferable to use a supply of 'soft' water. We have used rain water collected from the roof of the building but this is not satisfactory because of contamination by organic material, rotting leaves, etc., which is not removed by the deionizer. Boiler water condensate from the hospital heating plant was tried. This contained large amounts of ammonia derived from the material added to the boiler feed water to prevent scaling of the boilers. The system of treatment of the boiler water was altered, to exclude the use of ammonium salts, this produced a condensate which is of good quality and suitable for use in the deionizer.

The deionizer used was an Elgastat B. 102* The production of reasonably large volumes of deionized water using this apparatus is rather laborious and requires constant attention when condensate is used because only small quantities (about 1 l.) can be fed into the feed reservoir at a time. This has to be manually lifted and poured into the reservoir. Attention is required to see that the cartridge containing the resin does not run dry. This is not a convenient arrangement in a busy laboratory.

The device described below was designed to overcome these difficulties, enabling the production of reasonably large volumes of deionized water with the minimum of attention and manual effort.

Description of the Device

The deionizer itself requires only small modification (Fig. 1.) The overflow pipe (P) at the top of the reservoir (R) is closed by a blocked rubber tube. The hole (H) in the top of the reservoir (R) is fitted with a rubber bung (B) drilled to carry through its centre a piece of glass tubing (T_1) of 7 mm. diameter ending 3 in. below the bung. The following additional pieces of apparatus are required:

One or more containers of fairly large capacity for the supply water. We have found that carboys† in rigid polythene of 15 l. capacity are suitable. These are fitted with side handles which facilitates transport from

*Elga Products Ltd., Lane End, Bucks.

†Autodevices Ltd., 42 Charles Street, Barnes, London, S.W.13.

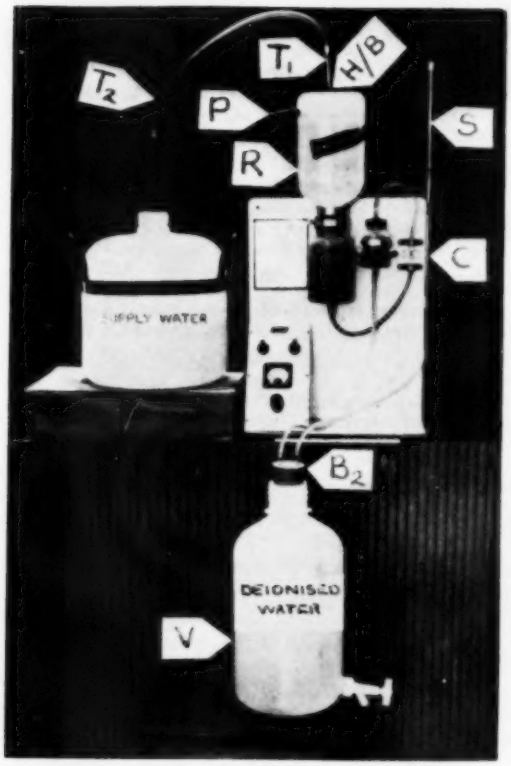


Fig. 1.

the boiler house. They are not too heavy to handle and provide a reasonable volume of water for one flow.

A piece of P.V.C. transparent tubing (T_2) about 30 in. long attached to tube T_1 and dipping to the bottom of the supply carboy.

A receiver for the deionized water (V), this is of rigid polythene and approximately 9 l. capacity. It is fitted with a tap at the bottom. The top of this container is fitted with a rubber bung (B_2) which has been drilled to take two pieces of 7 mm. glass tubing. One of these is connected to the deionizer output by means of P.V.C. tubing and passes to the bottom of the receiver. The other tube is connected to the 'switch-off ' tube (S) and projects only a short distance into the receiver. The 'switch-off ' tube (S) is a piece of straight glass tubing 7 mm. in diameter and about 18 in. long mounted so that the open end is slightly higher than the top of the reservoir (R).

Operation

The various parts of the apparatus are set up as shown in the illustration so that the receiver is below the level of the bench carrying the deionizer and the supply container.

The reservoir (R) is filled with supply water. The flow through the apparatus is started by opening tap (C) taking care to see that all air bubbles are expelled from the system.

The flow is stopped by turning off tap (C) and the rubber bung (B) is placed into the top of the reservoir (R). The tube (T_2) is inserted into the supply carboy. On opening tap (C) the supply water will now flow from the carboy, through the deionizer and into the receiver. when the receiver has filled, the level of water will rise in the 'switch-off ' tube (S) until it reaches the level of the supply water. The flow through the apparatus will then stop. When water is drawn from the receiver for use, the flow through the apparatus will automatically start again. Thus a supply of 9 l. of deionized water is maintained available so long as the supply carboy is not allowed to become empty.

The rate of flow may be increased by raising the supply container above bench level. In the photograph it is raised 5 in., giving a yield of 16 l. per hour.

Should the water fail to flow through the apparatus this may be due to air leaking into the system. The apparatus should be checked for air leaks, any accumulated air bubbles can be removed by raising tube (T_2) to expel the air and then returning it to the carboy.

We have found that this device works very satisfactorily and produces a very high grade of 'distilled' water with the minimum of attention.

AN EFFICIENT ANTI-BUMPING DEVICE FOR CRUDE FIBRE DIGESTIONS

by R. M. Allison

Crop Research Division, D.S.I.R., Lincoln, New Zealand

DURING the digestion of feeds and faeces for crude fibre determinations, frequent trouble arises due to the 'bumping' of the digests in 1·25 per cent acid and especially in 1·25 per cent alkali. In this laboratory these digestions are performed in tall form, unspouted Berzelius beakers with cold bulb condensers made of close-fitting round-bottom flasks. It was discovered accidentally that an inverted funnel with the stem removed or greatly reduced in length prevented superheating of digestion mixtures. Such boiling cones were subsequently made from funnels of similar diameter to that of the Berzelius beakers. Their action was improved still further by making four to six deep notches in the rim. The manner in which superheating is prevented can be easily observed in practice. The turbulence created by heating the digestion mixture causes rapid circulation of the beaker contents up through the inside of the cone, out of the truncated end below the surface of the digest, and down the sides of beaker and cone through the notches in the cone rim. Sets of funnels have been made to fit different diameter beakers and the height of the cone adjusted so that the apex is just below the liquid level in the beakers. Very efficient digestion results from the use of these cones with complete elimination of 'bumping'.

THE LABORATORY APPARATUS AND MATERIALS EXHIBITION

June 19 to 22, 1961

LECTURE PROGRAMME

THE Second Laboratory Apparatus and Materials Exhibition, sponsored by this Journal and organized by U.T.P. Exhibitions Ltd., will be held at the Royal Horticultural Society's New Hall, Westminster, London, from June 19-22, 1961. This exhibition, organized on a national scale, covers products, equipment and materials limited to those specially produced for use in all types of laboratories.

Practically every possible laboratory requirement will be available for examination, study, comparison and selection.

In addition, a comprehensive series of lectures on recent advances in laboratory techniques by specialists in their field will be given throughout the entire run of the Exhibition and the full programme is given below.

Date & Time	*Lecturer*	*Subject*	*Chairman*
June 19, 1961 10.00 a.m.	W. E. Hoare, D.Sc., F.I.M., Ass. Director, Tin Research Institute, London.	'Recent Advances in Techniques at the Tin Research Laboratory'	Prof. S. Tolansky, D.Sc., Ph.D., D.I.C. F.Inst.P., F.R.S.
11.30 a.m.	L. C. Nickolls, M.Sc., A.R.C.S., D.I.C., F.R.I.C., Director, Metropolitan Police Laboratory.	'Recent Advances in Forensic Laboratory Techniques'	J. G. Davis, D.Sc., Ph.D., F.R.I.C.
3.00 p.m.	P. N. Campbell, Ph.D., Courtauld Institute of Biochemistry, London.	'The Electron Microscope in Studies of Protein Synthesis'	E. Hindle, M.A., Sc.D., Ph.D., F.R.S.
June 20, 1961 10.00 a.m.	W. H. Lee, Ph.D., F.R.I.C. Battersea College of Technology.	'Radio-frequency Methods in Analytical Chemistry'	Prof. C. W. Davies, D.Sc., F.R.I.C.
11.30 a.m.	D. Gross, Ph.D., Tate & Lyle Ltd.	'High Voltage Paper Electrophoresis'	Prof. E. J. Bourne, Ph.D., D.Sc., F.R.I.C.
3.00 p.m.	J. R. Busvine, D.Sc., Ph.D., Reader in Entomology Applied to Hygiene, London University.	'The Biological Assay of Insecticides'	A. J. Amos, Ph.D., F.R.I.C.
June 21, 1961 10.00 a.m.	I. D. P. Wootton, M.A., M.B., B.Ch., Ph.D., Post-Graduate Medical School.	'Automation in the Medical Laboratory'	Prof. Sir Charles Dodds, M.V.O., M.D., D.Sc., F.R.C.P., F.R.S.
11.30 a.m.	S. F. Suffolk, B.Sc., National Institute for Research in Dairying.	'Laboratory Workshops'	Prof. G. I. Finch, M.B.E., D.Tech., F.Inst.P., F.R.S.
3.00 p.m.	W. I. Stephen, Ph.D., Birmingham University.	'The Weisz Ringoven Technique in Microchemistry'	Prof. R. Belcher, D.Sc., F.R.I.C.
June 22, 1961 10.00 a.m.	R. P. W. Scott, B.Sc., Benzole Producers Ltd.	'Vapour Phase Chromatography'	Sir Robert Robinson, O.M., M.A., D.Sc., Sc.D., LL.D., F.R.I.C., F.R.S.
11.30 a.m.	D. A. A. Mossel, Ph.D., Nutrition Research Institute, Netherlands.	'Modern Methods for the Microbiological Examination of Foods'	Prof. A. A. Miles, C.B.E., M.A., M.D., F.R.C.P., F.R.S.
3.00 p.m.	Prof. A. C. Frazer, M.D., D.Sc., F.R.C.P., Birmingham University.	'The Examination of Food Additives'	Prof. H. D. Kay, C.B.E., D.Sc., Ph.D., F.R.S.

CHEMICAL STERILIZATION

by J. G. Davis, D.Sc., Ph.D., F.R.I.C., M.I.Biol., F.R.S.H.

Dr. J. G. Davis and Partners, 9 Gerrard Street, London, W.1

PHYSICAL conditions such as heat and radiation, and chemical substances which destroy micro-organisms are the two broad groups of agencies used for sterilization or disinfection. The main fields of application are medicine and public health, the food industries, especially those concerned with highly perishable foods such as milk, and also water.

The classical meaning of the words 'disinfection' and 'sterility' are still valid, but new terms have been introduced and the classical terms are sometimes used with a modified meaning. Thus the terms 'antiseptic', 'disinfectant' and 'sterilant' are used for similar substances, and 'disinfection', 'sterilization', 'commercial sterilization' and 'near-sterilization' for similar processes. Whereas the term 'disinfectant' usually implies a powerful germicide with no specific qualifications, 'antiseptic' usually implies a germicide with negligible irritant effect on the tissues. The term 'sterilant' is used in the food industry, possibly because 'disinfectant' so often implies a strong smelling phenolic substance.

Sterility means 'incapable of proliferation', and so in the hygienic sense the complete absence of all forms of life. The word is sometimes used more loosely to indicate absence of pathogens, or absence of food spoilage organisms, the small numbers of harmless organisms being ignored. The word sterility should *always* be used in its strict sense; sterility, like virginity, cannot be qualified. A thing is either sterile or not.

In practice the destruction of pathogens or spoilage organisms is often sufficient, and the terms 'disinfection', 'commercial sterilization' and 'near-sterilization' are then used. The first is accepted in medical work, and of the other two the latter is to be preferred. Appropriate tests are examation for surviving pathogens, where *E. coli* type I is sometimes used as an index which implies dangerous contamination, and for surviving spoilage organisms a maximum total count may be used as a convenient index.

Cleaning and Sterilizing – Cleansing

The modern fashion of chemical disinfection has tended to reduce the significance of cleaning, which is of the greatest importance in all aspects of sterilization. Cleaning may be defined as the complete removal of all extraneous material and especially organic matter, which is food for bacteria. Heat may in time penetrate a film of milk-stone, dried-on-egg, serum or pus, and kill any micro-organisms present, but such films may protect organisms indefinitely against all types of chemical sterilants or radiation. Apart from this, efficient cleaning removes mechanically about 99 per cent of the bacteria on a dirty object, and is, therefore, an integral part of the sterilizing process. Cleaning and sterilization, whether by heat or chemicals, are complementary processes. The term 'sanitization' is commonly used in North America for this combined treatment, but this term, although etymologically correct, is not popular in Britain. A convenient term for the combined treatment is 'cleansing'.

In the food industries cleansing may be defined as 'the complete removal of all extraneous matter and reduction of micro-organisms to 1 colony per sq. cm. area or per ml. capacity by standard tests'[1]. Organisms surviving are almost invariably spores and resistant cocci of no pathogenic or

TABLE I

Summary of standard methods for cleaning and sterilizing

	Plant	*Tanks and tankers*	*Pipelines (mains)*	*Cans*	*Bottles*
Pre-rinsing ..	Cold water	Cold Water	Cold water	Cold or warm water	Cold or warm water
Cleaning ..	1. Scrubbing with detergent 2. Recirculation with detergent 3. Recirculation with ½-1 per cent nitric acid	Scrubbing with detergent	As for plant	Jetting with or without detergent (brushing)	Jetting or soaking with detergent
Rinsing after detergent ..	Hot water	Hot water	Hot water	Hot water	Warm water
Sterilizing ..	Steam, hot water, chlorine, 'quats', nitric acid	Chlorine, 'quats', hot water, steam	As for tanks	Steam ('quats', etc.)	(Hot detergent sterilizes) (steam)
Final rinsing ..	Water—if chemicals used	Water—if chemicals used	Water—if chemicals used	—	Water (unless steamed). May be chlorinated 5 p.p.m.

TABLE II

Special precautions

	Cleaning	*Sterilizing*
Steel	Any alkali	Not chlorine
Stainless steel.. ..	Nitric acid can be used	Chlorine if pH 9 or above. Nitric acid possible
Aluminium	No acids of caustic alkalis. At least 25 per cent silicate	Not chlorine
Glass and coatings ..	Anything except strong alkalis	Anything. Sudden and considerable temperature changes undesirable

industrial significance. The validity of this practical definition is well borne out by the fact that when swab and rinse test results are less than 1 per sq. cm. or ml., presumptive coliforms are very rarely, if ever, found. Absence of this most useful index organism usually indicates that all ordinary pathogens and most spoilage organisms have been killed. Spore forming organisms are an unfortunate exception (cf. p. 308) and when destruction of these is necessary, much more drastic methods must be employed. Standard methods for cleaning and sterilizing food equipment are given in Table I and precautions to be observed with various materials in Table II.

Bactericides and Bacteriostats

The generally accepted definitions are that a bactericide kills bacteria, whereas a bacteriostat merely prevents growth or proliferation. In practice this distinction may be difficult to sustain: vegetative cells of bacteria which cannot grow usually die, although sometimes very slowly. The difference in effect may be a matter of time, concentration and temperature. Proliferation of cells as measured by colony counts may not be the only form of growth of bacterial cells. All methods of assessing bactericidal and bacteriostatic power are dependent on the technique used. For practical purposes we may assume that if cells cannot be recovered by growth tests after removal of the chemical, then the action is bactericidal. If cells are recovered and grown, then the action is bacteriostatic. It is often difficult to decide when a cell is dead, and this is only one of many reasons why laboratory tests may be an unreliable guide to the efficiency of a germicide in practice.

Chemical Sterilization Compared with Steam and Boiling Water

Where feasible steam or boiling water, or both, are usually the best agents for sterilization in industry. However, circumstances are often such that chemical sterilization is preferred. Thus the use of heat may be impossible, as for human skin and tissues, for equipment made of thermolabile material such as glass or plastics, or for heat-sensitive components or finishes. Heat is difficult to apply to large surfaces such as open tanks and walls. It may not be economic if items at various points have to be sterilized rapidly at various times of the day and night. Chemical solutions can easily be stored in concentrated form in any convenient place, and are always ready for use at a moment's notice. An adequate supply of steam may not always be available. If equipment is required to be used cold immediately after sterilizing, steam and boiling water are obviously unsuitable.

Quite apart from convenience and efficiency, chemical sterilization is often cheaper than steam. As with detergents, sterilizing solutions can be run from equipment requiring the most thorough cleansing to other equipment where the standard required is not so high.

Sterilants Compared with Heat for the Destruction of Spores

Spores constitute a special problem in sterilizing work, and unfortunately some spore-formers are extremely important, for example, *Cl. tetani* and *B. anthracis* in medicine, *Cl. botulinum* in canning, and *B. cereus* in pasteurized milk. The only effective ways of destroying spores with certainty are by autoclaving, for example at 120° for 20 minutes; or by dry heat, for example 170° for two hours; or by high concentrations of suitable germicides at higher temperatures than those that are adequate for the cleansing of equipment.

The ordinary treatments which are satisfactory for vegetative cells may be useless against spores.

Commonly Used Sterilants in Industry

Hypochlorites.—Of all sterilants, chlorine or hypochlorite is the best from most points of view. It is cheap, convenient to use, powerful and has a wide antibacterial spectrum. Its greatest disadvantages are corrosiveness and odour. The former can be minimized by using in cold solutions and at pH 9 or higher, but it is more bactericidal at neutral or acid reactions. Commercial preparations usually contain 9 to 12 per cent and domestic preparations about 1 per cent of available chlorine. Complete immersion in 150 to 200 p.p.m. hypochlorite will sanitize clean metal and glass in two minutes; 10 minutes gives an ample margin for sterility.

Quaternary ammonium compounds.—Next to hypochlorite the quaternary ammonium compounds are probably the most useful. They are convenient to use, of very low toxicity to animals, without appreciable odour or taste, non-corrosive, and not too expensive. They are very powerful against Gram-positive but are nearly always less effective against Gram-negative organisms, and this is their greatest disadvantage. They are incompatible with soaps and anionic detergents, but can be used with most alkalis and non-ionic detergents. Alkalinity increases their bactericidal power.

They are only very weak detergents. The relative advantages and disadvantages of steam, hot water, chlorine and the quaternary ammonium compounds are given in Table III.

Working concentrations vary from 1 in 1,000 to 1 in 20,000 according to the particular quaternary compound used, the temperature, the time, the alkalinity and the percentage kill desired. Weight for weight they are less effective than chlorine, but their other advantages may outweigh this fact.

TABLE III

Sterilizing agents—advantages and disadvantages

	Steam	*Hot water (190° F.)*	*Chlorine*	*Quaternary ammonium compounds*
Cost	Varies	Varies	Low	High
Convenience..	Depends on layout	Recirculatory system necessary	Very convenient	Very convenient
Penetration ..	Good if adequate supply	Good	Clean plant essential	Clean plant essential
Heating effect	Tanks, etc., may require hours to cool. Undesirable stresses may be set up	Less than steam	None or slight	None or slight
Suitability ..	Very suitable for enclosed systems and small articles in chests	Very suitable for pipelines (mains)	All purposes	All purposes
Persistence ..	Not persistent	Not persistent	May persist if traces chlorine, etc., remain	
Corrosion ..	None	None	Extremely corrosive especially at acid and neutral reactions	Not corrosive if thoroughly rinsed away
Odour ..	None	None	Very marked	None
Toxicity ..	None	None	Precautions essential	Not toxic in practice

For detailed information on the quaternary compounds see Glassman[2], Lawrence[3] and Resuggan[4].

Alkalis.—Although generally regarded only as detergents, caustic alkalis have, in addition, a strong germicidal activity. Thus in bottle-washing, bottles emerging from the detergent section, 3-5 min. in 0.4 per cent NaOH (equivalent) at 145° F. are usually sterile or nearly so[5].

The bactericidal effect falls rapidly with decreasing pH and is influenced by the nature of the anion (Table IV).

Hot caustic soda solutions at 1-3 per cent are specially useful for killing spores, and this is an advantage claimed for the soaker type of bottle-washing machines.

Iodine.—Although very useful as an antiseptic, iodine has certain disadvantages as a sterilant. It has a powerful odour, stains badly, is not very soluble in water, and is expensive. It is readily soluble in iodide solutions and alcohol, but this method increases its cost, and the solution may be irritant to skin.

TABLE IV

Bactericidal activity of alkalis

	pH of 1 per cent solution	*Killing time in minutes against* B. subtilis *spores at 30°*
Sodium hydroxide	13·1	Less than 5
Sodium carbonate	11·4	Less than 5
Trisodium phosphate ($12H_2O$)	12·0	30
Sodium sesquicarbonate ..	9·9	More than 60

Idophors.—Although of recent introduction, it is probable iodophors will grow in popularity. They are prepared by the action of iodine on non-ionic detergents in acid solution, and they have both detergent and sterilising properties. They are in use in North America[6]. It is claimed that the iodine in this solubilised form has about the same killing power as the available chlorine in hypochlorites.

Chloro-compounds.—The usefulness of the chlor-phenols and related compounds is well established, but they are odorous and may be irritant. Chloramine-T does not suffer from these disadvantages, but is rather mild in action. Amongst interesting new compounds are dichlorocyanuric acid and dichlorodimethyl hydantoin. It is claimed that these are of extremely low toxicity and are non-irritant.

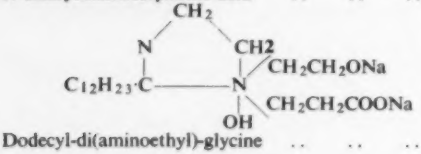
Dichlorophene is more effective against Gram-positive organisms and fungi than hexachlorophene. Both have recently become popular as antiseptics. The latter has a phenol coefficient of about 40 against *Staph. aureus* and of about 15 against *Salm.typhi*.

Vigorous claims have been made for the efficiency and general suitability of chlorhexidine diacetate and the chloroxylenols as antiseptics. The odour of some of these substances makes them unsuitable as sterilants.

Amphoteric or ampholytic compounds.—These are mostly alkylated amino acids possessing amphoteric properties, for example dodecyl β-alanine[7]. They possess many advantages according to their sponsors. Thus they are good wetting agents and fairly good emulsifiers. They are compatible with anionic, non-anionic and cationic agents. Typical examples are given in Table V.

TABLE V

Amphoteric (ampholytic) surface-active germicidal agents

Chemical name or formula	*Trade name*	*Manufacturer*
Dodecyl-β-alanine	Deriphet	General Mills
Dodecyl-β-aminobutyric acid	Armeen Z	Armour
N-Laurylaminosulphonic acid	Siposan	Sipon
	Miranol	Miranol Chemical
Dodecyl-di(aminoethyl)-glycine	Tego	Th. Goldschmidt

The Importance of Specificity

Micro-organisms vary widely in their resistance to adverse conditions and to lethal agents. A good example is the difference between *N. gonorrhoeae* and the spores of *B. subtilis*. The former quickly dies outside the living animal; the latter may require 1 per cent NaOH for some minutes to achieve a 99·99 per cent kill. Compared with other organisms *Myco. tuberculosis* is highly resistant to most chemicals, especially acids, and yet is rapidly killed by direct sunlight and 70 per cent ethanol. The quaternary ammonium compounds are effective against most Gram-positive bacteria but relatively feeble against the Gram-negative, and especially *Ps. pyocyanea*. Disinfectants can be highly specific in their action, and in choosing a disinfectant consideration must always be given to this fact.

The Danger of Generalizing on the Use of Germicides

Many factors influence the effectiveness of any one germicide for a given purpose. The most important are (i) concentration, (ii) temperature, (iii) time of contact, (iv) pH, (v) amount and kind of organic matter, (vi) types of organism present, and the type selected for assessment purposes, and (vii) physiological condition of organisms. Other factors of minor importance also exert some influence. For this reason it is unsound to make comparisons between disinfectants. Just as it is essential to specify techniques in detail when evaluating disinfectants in the laboratory, so it is essential to specify practical conditions of use when comparing sterilants. The rating of a disinfectant for use as a rinse solution for beer glasses, might prove to be very different when used for pipelines in a dairy. The former must be used quickly in the cold at pH 6-8; the latter can be used for some time at a high temperature at any required pH value.

The Significance of Organic Matter

The commonest cause of failure to achieve sterility, or adequate cleansing, is generally the incomplete removal of organic matter, for example milk-stone on pasteurizing plant, grease on skin, protein-fat residues on dishes. Such organic matter can interfere in two ways. As a firm film on the object it can act as a barrier between cell and germicide. If it becomes detached and goes into colloidal solution or suspension in the disinfecting liquid it competes with the cells for the disinfectant and so reduces the concentration of disinfectant. Some types, for example the quaternary ammonium compounds, may be inactivated by chemical combination with anionic material, or by adsorption on suspended matter.

The Nature of the Material

Smooth non-absorbent materials such as glass and stainless steel are easy to sterilize. Rough absorbent materials such as all animal and vegetable matter, rubber, plastics and textiles, are difficult if not impossible to sterilize. With these, sterilization is entirely a matter of contact between sterilant and germ cell. If contact can be established by penetration (for example, of skin by 70 per cent ethanol) or soaking (for example, of blankets and napkins in a quaternary compound or in chlorine solution), then sterilization or cleansing is quite feasible. Sterilization may require much longer times, higher concentrations and higher temperatures.

The Nature of the Surface

One of the most important lessons which has been learned by industry and manufacturers of food equipment is the necessity for a smooth finish to, and absence of crevices and dead ends in, all items which come into contact with food, because they are difficult to free from traces of organic matter, and may escape contact with cleaning and sterilizing solutions by reason of air-locks. Losses to the food industry from this cause alone must have been great in the past; fortunately the lesson has now been well learned.

Corrosion

The biggest problem in chemical sterilization, and certainly the greatest disadvantage of chlorine, is corrosion. This may not be realized until it is too late, and damage to the extent of hundreds or thousands of pounds has been done.

Enthusiasm in sterilization should always be tempered by a fundamental knowledge of the method. As with other developments in industry, manufacturers often acquire experience at the expense of their customers.

The fundamental aspects to consider when using hypochlorite or other corrosive sterilants are (i) to ensure a clean surface, (ii) to use the correct concentration of available chlorine (p.p.m.), (iii) to use cold or barely warm water, (iv) to use for the correct time, for example, 10 minutes (v) to rinse *immediately* with sterile water (5 p.p.m.), and (vi) to sterilize just before use.

The practice of leaving a closed circuit system full of weak hypochlorite solution overnight is not necessarily wrong, but this must be carefully controlled. The equipment must be corrosion-resistant (for example, stainless steel or glass) and the solution must be weak, alkaline and cold.

Recontamination

Methods of sterilization are sometimes condemned as the result of tests on the product or on the equipment, when the

real cause of failure is recontamination. This is particularly true in bottle washing. Both manufacturers and users of bottle-washing machines are sometimes oblivious of the fact that although their detergent section efficiently cleans and sterilizes the bottles (p. 311), these are then immediately sprayed with a warm rinse having the bacteriological properties of sewage. Although finishing with a mains water rinse it is not surprising that unsatisfactory bottles are obtained. With any machine all rinse tanks should be drained every day and the addition of a sterilant such as hypochlorite or a quaternary compound sufficient to exert a bacteriostatic effect is advantageous. Constant bacteriological control of rinse tanks is essential, and the count should never rise above 1,000 per ml. A final mains rinse should then be sufficient to ensure satisfactory bottles (p. 311). It is always sound practice to clean immediately after use, and to sterilize immediately before use.

Industrial Practice

The more perishable a food, the better it is as a medium for micro-organisms, and the more important it is to ensure sterility in the food equipment and the containers. Even if the packaged food is sterilized afterwards, a cleansed bottle or can is advantageous. The modern food technologist must *ipso facto* be a microbiologist. Apart from problems of keeping quality, high moisture foods in the pH range 6 to 8, such as milk and meat stews, are good media for the growth of pathogenic organisms, and so there is a double reason for observing the most stringent hygienic precautions in processing.

The Dairy Industry

Milk is our most perishable food and the dairy industry has attracted more legislation than any other branch of the food industry. For many years hot water and steam were the only permitted means of sterilizing equipment, and rigorous requirements were laid down in the Milk and Dairies Order, 1926. During the 1939-45 war necessity brought about the introduction of new methods and the Milk and Dairies Regulations, 1949 (now 1959), permitted the use of approved sterilizing solutions. The cleaning and sterilizing problems in dairying are diverse and (cf. Table I) the spraying of a chemical solution is often more convenient than the use of steam. Dairy plant lends itself particularly to circulation methods of cleansing and in-place methods (see p. 312) are now being introduced. Cleaning and sterilizing in the dairy industry have been revolutionized in the last 30 years and are now highly efficient and scientifically controlled processes. Chemical sterilization is almost universal in the dairy industry today, but only approved sterilants may be used[8]. Hypochlorites and quaternary ammonium compounds are the commonest but iodophors are being introduced[9]. The ubiquitous use of chlorine, and of acids for descaling and in-place cleaning (p. 312) has been made possible only by the now almost universal adoption of stainless steel for all dairy equipment, apart from glass and plastic for certain types of pipelines. Manufacturers have played an essential part in the revolution in sterilizing methods in the dairy industry, and the highest praise must be given to them for their initiative in this respect. In the 1920's equipment was made in tinned copper and iron, and badly designed from the bacteriological aspect. Today a modern processing dairy might be described as a 'hygienist's paradise'. (For details of sterilizing methods in the dairy industry, cf. ref.[1], [9–12]).

The Brewing Industry

The brewing industry has two important advantages over dairying. Its processes are not controlled by specific legislation, and beer may rightly be regarded as a mild antiseptic, so that the adage 'beer is good for you' can be interpreted in more than one sense. Caustic soda and hot water and steam have for long been the classical cleansing agents in the industry. Brewers are extremely jealous of the organoleptic properties of their product and consequently do not countenance the introduction of anything which might affect it. Chlorine is well known to produce highly odiferous chlorphenols with traces of phenolic bodies in foods, and for this reason it is ruled out for certain branches of the food industry. Another aspect is that copper equipment is still common, and so corrosive sterilants are out of the question. Thus the brewing and dairy industries afford an interesting comparison of the influence of materials on sterilizing methods in industry. There is also an interesting comparison of the influence of the product on the criteria for disinfection. Pathogens, coliforms and all lactose-fermenters, and *B. cereus* a cause of 'sweet curdling' or 'bitty cream' are the most feared in milk. With beer, yeasts, lactobacilli and certain streptococci or pediococci are the organisms to be destroyed. Beer has never been the cause of any infectious disease, and so pathogens are of little significance. The quaternary ammonium compounds are suitable for treating beer glasses[13].

Food Manufacture

Each branch of the food industry has its own problems. As with catering, some of these have blissfully ignored the requirements of hygiene in the past because no problem has been apparent. The Food Hygiene Regulations, 1955, should be regarded as only the start of a drive for hygiene in every branch of the food industry. For some branches of the food industry the requirements are not so severe as those for the dairy industry, so that if methods and standards adopted in the dairy industry are used a satisfactory level of hygiene should be obtained.

The Catering Industry

In the past the level of hygiene in the catering and food industries has often been low. The Food Hygiene Regulations, 1955, constitute a much needed step forward, but there are no instructions regarding sterility or to methods for sterilizing food equipment. The difficulties are obvious, and there is less need for the introduction of chemical sterilization than in other industries. A suitable treatment for crockery, cutlery and food utensils is thorough cleaning followed by a short immersion (minimum 30 seconds) in water at about 180°F. Alternatively the use of a germicidal detergent is advisable. For hand washing, where the maximum workable temperature is 120°F., such a preparation can give crockery free from pathogens. Mops and dish cloths should be 'boiled' daily.

Bottles

With reasonable care it is easy to cleanse bottles for any industry using mechanical washers. Efficient pre-rinsing and jetting (or soaking and jetting) with detergent solution at the right temperature are more important than the selection of any one detergent. The pharmacist washing bottles by hand may with advantage use a germicidal detergent as advised above for the catering industry. Recontamination (p. 311) is the greatest danger. Provided that the bottle is efficiently treated, the presence of foreign objects and impervious

matter such as concrete or paint does not constitute a public health hazard[14]. A most useful and practical book on bottle washing is that by Resuggan[11].

In-place Cleaning

With rising labour costs automatic methods of cleaning and sterilizing have received a good deal of attention in industry. There is little doubt that in time all cleaning and sterilizing will be automatic. The two essentials are a closed circuit system and the complete absence of corrodible items. A typical sequence as used in a modern dairy is as follows:

	Minutes
Cold water rinse	5
Hot detergent circulation	10-20
Cold water rinse	5
Cold chemical sterilant or hot water circulation	15
Sterile water rinse	5

In-place methods are specially suitable for acid methods. In Europe, outside Britain, cold nitric acid 0·5 to 1 per cent is often used to clean and sterilize, and equipment such as pasteurizing plant is rarely dismantled. Acid methods are not in general use in Britain (cf. ref.[9]).

Enclosed Spaces

The best way of ensuring a 'clean atmosphere' is efficient air conditioning incorporating bacterial filters. Aerosol disinfectants have been accepted as the best 'chemical method' of disinfecting air, but there is a natural prejudice against breathing even minute quantities of chemicals. Where a room or chamber can be sealed, formalin vapour is probably still the best, especially for efficiency and cheapness. Ethylene oxide and, in the U.S.A., β-propiolactone, have been used successfully[15]. In all vapour methods the relative humidity is an important factor. This should be at least 70 per cent.

Textiles

The sterilization of blankets, sheets, pillow-cases, baby napkins and all similar articles is each one a special problem depending on size, thickness, and nature of material. Penetration is essential, and drastic treatment may harm or shrink the fabric. 'Boiling', the classical procedure, may be undesirable because of the odours and water vapour produced, and is a cumbersome procedure for large articles. This is a field where chemical sterilization can be used with advantage. Provided a proper procedure is adopted in hand or machine-washing effective sterilization can be achieved[16]. Quaternary ammonium compounds are commonly used for this purpose, and their ready adsorbability introduces special problems[17]. Surface treatment will affect the extent of adsorption. McNiel and others[18] found that vegetative cells of *B.cereus* and *Brevibacterium ammoniagenes* were very sensitive, *Staph. aureus* more variable, and *Proteus* highly resistant to a benzyl quaternary ammonium compound.

Water

The basis of public health is a clean and safe water supply, and the sterilization of water is the mother of all developments of industrial sterilization. Water almost inevitably comes into contact with equipment, and mains water is usually of very low bacterial count. However, in factories water can easily become contaminated, and the residual chlorine is usually inadequate to prevent this. The bacteriological quality of all water used in a factory should be carefully controlled[19].

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CORRESPONDENCE

To The Editor,
Laboratory Practice.

DEAR SIR,—Your February editorial concerning the supply of laboratory equipment, was missed due to my being away from England on business. It has now been brought to my notice and I would like to comment if it is not too late.

You list the various ways of bringing scientific apparatus to the notice and knowledge of the scientist, and claim that the independent assessment published in a trade magazine is the best possible method. There is no doubt that these reviews are extremely valuable, both to the manufacturer and the prospective buyer, but surely it suffers from the same drawback as advertisements and circulars. If the apparatus reviewed or advertised is not required at the time of reading, or already planned for the future, my experience is that it is neither remembered, nor filed away in order that it can be brought to light when there is a requirement for that item. There is an excellent domestic consumers' guide now published, and many of the professional chemists, physicists etc., subscribe to it. They read it, note mentally that 'X' refrigerator or washing machine is better than 'Y', but how many remember six months later when they decide to buy that very appliance. Very few.

One buyer/seller link missed from your list was the comprehensive catalogue, provided at great expense by the supplier, but absolutely essential. In the majority of all scientific purchases, it is the only method of determining the apparatus to be purchased.

Finally we come to representatives, surely these are the most valuable when non-routine buying is considered. Basically the scientific representative comes in two distinct forms. The specialist and the general wide range man. The specialist is usually a very highly qualified man, and would normally be employed by an organization supplying a small range of highly technical instruments, e.g. electronic equipment, high grade

analytical balances, or specialist engineering apparatus.

These men have, without a doubt, a first class technical knowledge of their equipment, even covering in many cases the characteristics of the electronic components used, analysis of the metallurgical components and the mechanical strength of parts. They conserve their mental reservoirs of knowledge to their own special facet of the scientist's work, and within these sections, will answer and satisfy every question. The wide range man fulfils a different roll entirely, as my categorization implies, his knowledge is not of the super technical type, but is in the form of a general sensible knowledge of perhaps over 12,000 separate items, all relevant to laboratory work. He also acts as a link between different fields of activity, telling the biologist of a piece of standard metallurgical equipment or practice which will, with adaption, suit the narrow limits required for a new experiment in biological work, or, it may be he will inform the school chemistry master of a new industrial process which is relevant to general teaching, or the hospital of a special oil testing set, that could be used in a pathology laboratory. It is emphasized however, that it is essential that he be fully trustworthy where trade secrets are concerned; 99·9 per cent of technical representatives are fully trustworthy in this respect, and the odd exception who is not, soon becomes known for this trait, and is within a short time 'persona non grata' everywhere. Eventually due to his inability to gain admittance to laboratories, he resigns or is dismissed by his company.

It may be said that in these days of expensive catalogues, direct mailing of leaflets and news sheets, plus the existence of many trade magazines, devoted to bringing the new items to the notice of the users, that the representative is an unwanted luxury. This is not so. Apart from all other duties, he fulfils a psychological need. Why do many people after reading the menu in a first class restaurant, ask the waiter, 'Is the steak nice?' Do they expect the answer 'No, sir'. Of course not, what they require is confirmation on their own decision, and a little more technical information ('Yes, sir, it looks very fresh and tender') also someone to blame if things go wrong. The representative provides exactly the same function. The scientist for instance, has often decided to purchase a piece of equipment, but has his doubt about some particular point. He asks the visiting representative: 'Is this the right one for my job?' The resultant answer either confirms his original choice or proves to him that he was right to have his reservations. In answering the question, more technical information is passed, enabling the correct item to be purchased and finally the order is placed in the knowledge that the representative is always there to accept the partial responsibility should the information and decision still be the wrong one.

The point that the representative will always be there after the purchase is a very important one, for with the exception of a few particular specialist companies, the one sale is not the 'high point' of the customer/seller relationship. It is the continuance of trade, for the many hundreds of everyday items which is important. The customer must never be misled therefore. When an expensive item discussed with the representative during an interview, is delivered and put into use, the purchaser must be entirely happy and satisfied. This satisfaction thereby engenders goodwill and confidence, both to the man who advised and the supplying company.

Let there be no mistake, no scientist is 'sold' anything these days in the story book high pressure manner. He buys, after considering facts and relating them to his requirements. It is the representative's task to present these facts in a clear forthright manner, emphasizing the points where the attributes of the apparatus and the scientist's requirements are in harmony. Equally, any inherent quality which may conflict with the requirements must be made obvious.

Another use to which the representative may be put, especially if he is from a large company, is that of walking reference library. He will, by necessity, have attended more exhibitions than the scientist, as mentioned before, he will have visited a more varied collection of laboratories and have met a wider range of chemists, physicists, biologists, zoologists, pharmacists, pathologists, ergonomacists, etc., etc. He will have access to a large library of apparatus sources, and finally by virtue of his everyday job, have a versatile mind on the subject of the scientist's tools. No better person exists, therefore, to whom a current problem on apparatus or method can be put to and discussed.

Experience will, of course, grade the representative, as it does everyone. Both training and personality are important, but experience is the most important of all. Usually a man with a background of laboratory experience and near degree academic qualifications is selected as a future representative. He is given a thorough training in his company's clerical methods, and the company products. He is instructed in the ways of presenting himself and his company to the best advantage, and is instilled with the fact that the customer must be satisfied. During this period, he will attend exhibitions, meet customers, who visit the company's premises, and learn as much of ancillary trades and competitors' apparatus as he possibly can. He will then accompany an experienced colleague for a short while to absorb the system of arranging his calls and reporting his visits. Later he will be allotted an area of his own, and commence his round of visiting.

It is when he is on his own that he starts to build his knowledge and with a good representative, this will never cease. Within my own organization, there is a man who has been a representative for the company for over 30 years, and every day still adds to his knowledge of people, methods and apparatus.

This discourse on the representative has, I realize, taken a great deal of space, but I make no apology, for in my opinion, he is the main link between the scientific and the commercial world.

I am, sir, C. E. PASSMORE

Sales Manager (Midland Region),
Griffin & George (Sales) Ltd.

NEW INDUSTRIAL LABORATORIES

Balfour Group Research Centre

THE conception of the new Balfour Group Research and Development Centre at Leven shows a practical approach to all chemical engineering problems and provides the widest scope and facilities within a compact establishment.

The building houses a series of modern and well-equipped laboratories designed and made by the Group for the carrying out of research and development work in the design and operation of chemical process plant—with a wide range of industrial applications—and techniques of use and manufacture of materials of construction.

Integrated with the laboratories are comprehensive installations of pilot plant, encompassing the main types of processes and equipment, to demonstrate applications on clients' raw materials.

Complete processing systems can be analysed, tested and evaluated in terms of size, output, operation, number of stages involved, operating temperatures, flow arrangements and so on, so that the most efficient conditions for the production of a successful end product will be ensured before expense is incurred on installing full scale plant.

The plant layout has been largely designed on a 'Meccano' principle and the strategic deployment of equipment gives the utmost flexibility to every operation. For instance, it is frequently necessary to employ a series of unit operations or to combine several items of equipment to produce the most economical and effective process. The laboratories are so planned that plants can be changed from one process or raw material to another in the shortest possible time, with the help of interchangeable components and ancillaries.

This flexibility allows the Balfour Group to tackle any problem within the broad framework of chemical engineering from simple storage to a complete process.

Pilot plant is available for the study of drying, mass transfer, heat flow, reaction and kinetics, evaporation, distillation, fractionation, size reduction, mixing, emulsifying and so on. With this equipment and their specialized knowledge in the field of construction materials for corrosive conditions, high temperatures, high pressures and high vacuum technique, almost any plant can be designed and manufactured for the chemical, pharmaceutical, gas, oil, petroleum, food, dairy and brewing industries.

The technical problems of evaporation have received special attention by the Scott Division and the pilot plant is perhaps the most versatile in the Research Centre. Specially designed for rapid conversion to any of the many methods in use, it ensures that full-scale plant supplied gives optimum performance with lowest installation cost.

Molecular distillation is one of the most advanced developments made by the Group and can be thoroughly demonstrated and tested on new materials. Applications being actively pursued include distillation of materials with molecular weights above 250, which includes vitamins, hormones, sterols, plasticizers, petroleum fractions and vegetable oils.

A sludge pump for dealing with slurries and semi-solids can be studied under actual operating conditions. An interesting installation in the Centre is the new Scott-Wemco torque-flow pump, which has a recessed impeller completely out of the flow pattern and is virtually non-clogging. This enables it to handle high content slurries and sludges or the most fragile materials without damage.

The main chemical laboratories specialize in corrosion research, physical chemistry, metallography, chemical analysis, enamel and ceramic testing and specimen preparation.

One important section handles further development of the Pfaudler glassed-steel process to keep ahead of requirements for process and storage vessels using highly corrosive materials, like strong acids and alkalis, often at high pressure and temperatures.

A special solvents laboratory, isolated from the main block, handles processes where inflammable solvents and other noxious materials may be used.

A function of the Centre is the provision of training facilities in every sphere of chemical engineering. In conjunction with local technical colleges a student and graduate apprenticeship scheme exists by which suitable young men and women can reach full professional status in the best possible conditions while receiving industrial training. In certain cases, training facilities may be accorded to clients' personnel.

A valuable library and information department is also an important feature. Here the confidential technical design data is collated and augmented with published information from all sources and distributed to the Design Engineering Departments.

Comprehensive general services are also provided throughout the building and contribute largely to the speed and accuracy with which all problems, routine or otherwise, can be tackled. There is steam up to 300 p.s.i.g., compressed air at 10 p.s.i.g., vacuum, gas and water mains, electric busbars supplying various voltages, galleries giving access to plant at different levels, a 5 ton overhead crane and a fully equipped engineering and model shop.

Forthcoming Conferences

The 1961 annual meeting and summer conference of the Society for Applied Bacteriology will be held at Wye College, Kent, on Tuesday, Wednesday and Thursday, July 11, 12 and 13. The meetings will be held at Withersdane, Wye College, and accommodation will be provided at Withersdane and at the main College buildings.

General paper reading sessions and the annual general meeting will be held on July 11; a symposium on Bacteria of the Intestine, excursions and technical visits, and the Society dinner will be held on July 12, and on July 13 there will be symposium sessions on Bacteria of the Intestine.

LABORATORY APPARATUS AND MATERIALS EXHIBITION

The second national Laboratory Apparatus and Materials Exhibition will be held in the Royal Horticultural Society's New Hall, Westminster, from June 19-22, 1961.

Sponsored by *Laboratory Practice*, the exhibition is being held so that manufacturers of apparatus, materials and other products specifically produced for laboratories can show their equipment to scientists and laboratory executives in industry, research, education, medicine and national and municipal government.

LABORATORY EQUIPMENT & APPLIANCES

Neutron Generator Type NGH 150

This instrument has been designed to provide a source of neutrons of variable intensity and energy for use in the laboratory. The basic features are:

1. High neutron output.
2. Experimental flexibility.
3. Continuous or pulsed operation.

The instrument employs a D.T. reaction to produce 14 MeV neutrons. The deuterium ions are accelerated on to a tritium target, and the neutron output under continuous operation is of the order of 10^{10} neutrons per second. Fast neutrons can be moderated to produce thermal neutrons. The unit is continuously pumped and has an accelerating potential of 150 KV.

In addition to this application the instrument can be quickly adapted to provide accelerated ion beams of neutrons or protons for other nuclear physics applications.

The instrument would provide an extremely useful basic facility for colleges and universities for training in nuclear physics.

Another application, in the analysis of high purity materials, is the use of the neutron generator to irradiate samples for radioactivation analysis techniques.

The prototype instrument is currently being employed by the makers in the testing of fission chambers and other neutron detectors manufactured by the company.

(Manufacturers: 20th Century Electronics Ltd., Centronics Works, King Henry's Drive, New Addington, Croydon, Surrey).

High Temperature Incinerator

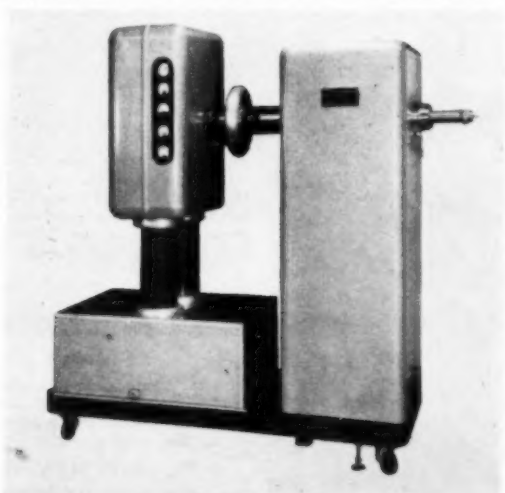
Designed for the complete destruction of waste materials and human tissue to meet the special requirements of hospitals and laboratories, a high temperature incinerator operated by gas and charcoal is now available. The incinerator, known as the GI.510, is a development of one originally introduced by R. & A. Main Ltd., with whom Stotts recently merged.

The GI.510 requires no special site and smoke from the flue is negligible. The combustion chamber is 13¼ × 13¼ × 16 in. high, giving an approximate capacity of 1½ cu. ft. with a 6 in. × 9 in. opening and is lined with durable refractory concrete bricks. In operation, a 4½ lb. charge of charcoal is placed in the incinerator (a suitable measure hopper is provided) and is brought to white heat by gas jets. The gas is then turned off and the fire continues to burn with intense heat for approximately 20 minutes, in which time the disposals from a 150-200 bed hospital can be incinerated. Overall dimensions: 24 in. wide, 24 in. deep, 47½ in. high.

GI 510 incinerator.

For use at sites where normal supply does not exist, model GI.510B is available for use with LP gas.

(Manufacturers: James Stott & Co. (Engineers) Ltd., Vernon Works, Oldham, Lancs.).



Neutron generator Type NGH 150.

This new spectrophotometer power supply unit, designed for use with the Unicam SP 500 spectrophotometer, sells at £55 ex-works. (*Manufacturers: Labgear Ltd., Cromwell Road, Cambridge*).

NEWS

General

Drawing Office Equipment and Materials

British, Continental and American products will be on show at the first national Drawing Office Equipment and Materials Exhibition to be held at the Royal Horticultural Society's New Hall, London, from June 5 to 8, 1961.

A special feature of this exhibition, organized by U.T.P. Exhibitions Ltd., will be a fully-equipped modern drawing office fitted with the very latest equipment. Materials and equipment for the drawing and design office in all branches of industry will be shown and demonstrated during this four-day exhibition and many new products will be seen for the first time.

New Ferranti Applications Laboratory

A new applications laboratory for proving the design and serviceability of silicon semiconductor devices has recently been completed by Ferranti Ltd. at their Gem Mill factory at Oldham, Lancs.

In the new laboratory, which has a floor area of approximately 3,000 sq. ft., a team of fully qualified semiconductor engineers are engaged on experimenting with silicon semiconductors and recording the results obtained in general and special applications reports, which are distributed to customers and potential customers throughout the world.

Typical of the important work now being carried out by the laboratory is the construction of a scale model of a 110kV., 2A, e.h.t. supply, for investigating problems associated with connecting large numbers of silicon rectifiers in series. These include unequal reverse impedances, unequal hole storage characteristics arising from the rapid rise times associated with the circuitry, and the problems surrounding the physical layout of the completed equipment which all accommodate about 2,000 rectifiers.

A considerable amount of experimental work is also carried out on the design of rectifier stack assemblies with the object of making them lighter and stronger. Hole storage characteristics and decay times of devices are being continuously investigated.

Manufacturers' News

Coldsealing Cuts Packaging Costs

Samuel Jones & Company Ltd. will soon be able to supply a variety of packaging materials coated with a substance that sticks only to itself, and then only when a predetermined pressure is applied.

Significance of this development, which stems from an agreement signed only a few weeks ago in Sweden, is that almost any package that is now heat-sealed can, in the not too distant future, be produced very much more quickly. Packaging machines, too, will be cheaper to buy and to maintain, and far easier to use. This is because heat-sealing takes time, and heat-sealing equipment is expensive to install and must be carefully controlled and maintained if it is to work efficiently.

Cohesive materials, on the other hand, can be sealed as fast as their surfaces can be brought together, or as fast as the goods can be fed to the wrapping point. They have in fact already stretched to the limit the present speeds of all the wrapping, sachet and pouch making machines on which they have been tested. There is no waiting for heaters to warm up—the machines are ready to run at the touch of a button.

Speed and ease of use are not the only virtues of these remarkable materials. They are odourless and non-toxic; they can be made to resist the passage of moisture-vapour or gases, or to permit the use of ethylene oxide for contents-sterilization after packaging; they can also be formulated to withstand sterilization by heat without affecting the reliability of the seal. Some kinds need heavy mechanical pressures to seal them together, but others seal with a finger-and-thumb pressure and can be repeatedly resealed by the consumer.

Q. & Q. Distributors

Quickfit & Quartz Ltd. have appointed Instrumentarium Oy, Alaksanterinkatu 15, Helsinki and Otto Gmur Inc., of Juan Luna, Manila, a Swiss firm with premises in the Philippines, as exclusive distributors for their products in Finland and the Philippines respectively.

Ion Exchange in Action

A private exhibition, organized by Elga Products Ltd., will be held at the Mitre Hotel, Oxford during the periods given below:

Monday, May 8, 12 noon-7 p.m.
Tuesday, May 9, 10 a.m.-7 p.m.
Wednesday, May 10, 10 a.m.-7 p.m.
Thursday, May 11, 10 a.m.-7 p.m.
Friday, May 12, 10 a.m.-1 p.m.

The exhibits will include: Bacteria-free and sterile deionized water for pharmacy, physiology and pathology; battery service: deionized water from tap; ion exchange in chromatography, analysis and separation; conductivity water from tap piped deionized water with end purification at point of use); control of deionized effluents—conductivity meters, line and dip cells, automatic control systems; decontamination of radioactive solutions by mixed bed technique; electronic work—transistor and semiconductor cleansing systems; syringe and medical instrument sterilization—solid free water for sterilizers; ion exchange in teaching and technology, chemistry, physics and field research; washing techniques—solid free water for washing of glassware and slides. There is no charge for admission, tickets are not required and refreshments will be served. A similar exhibition was also held in Cambridge from May 1 to 5.

Part of the new Ferranti applications laboratory for silicon semi-conductors.

Special Issue

The June issue of *Laboratory Practice* will contain a special section devoted to a preview of the exhibits to be shown at

THE LABORATORY APPARATUS AND MATERIALS EXHIBITION

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Samples from every batch of M&B laboratory chemicals are subjected to stringent tests by May & Baker analysts –you can be sure that each M&B chemical you use conforms to our high standards of specification.

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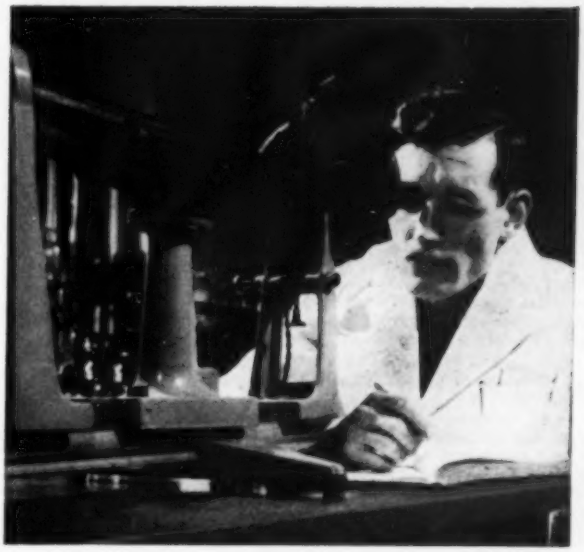

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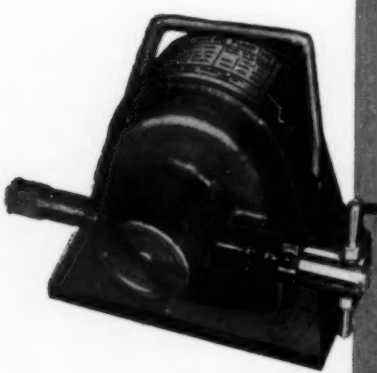

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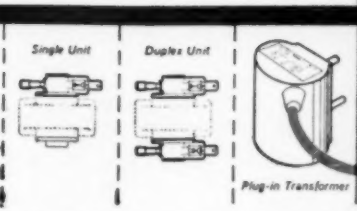

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CATALOGUES, BROCHURES & LEAFLETS

Received from Manufacturers

pH Meters.—Electronic Instruments Ltd., of Richmond, Surrey, have published a booklet describing a number of interesting pH meters manufactured by the company. Among these may be mentioned the direct reading model and the Vibron pH meter, the portable pH meter, two types of interest in the medical field and various industrial models, together with details of electrodes and electrode systems and various accessories.

Conductivity Meters.—The latest leaflet to be issued by the Loughborough Glass Co. Ltd., of Loughborough, Leics., describes their conductivity meters and Scalafix self-adhesive scales. These latter are made in transparent P.V.C., are resistant to water and a wide range of chemicals and are equally suitable for chemical plant and laboratory apparatus.

Macdonald Reagents.—A booklet has been issued by British Drug Houses Ltd., of Poole, Dorset, describing the reagents developed by F. J. Macdonald for the determination of fats in milk and milk products and also for testing separated milk and low-fat products.

MCP Publications.—Mining & Chemical Products Ltd., of 86 Strand, London, W.C.2, have recently published four booklets as follows: MCP 1 Semiconductors; MCP 2 Thermoelectric materials; MCP 3 Bismuth telluride semiconductors; MCP 5 Galvanomagnetic effects and materials. Copies of these booklets are available free from the company at the above address.

Electrophoretic Separations.—A new booklet has been issued by the Gelman Instrument Company of 106 North Main Street, Chelsea, Michigan, U.S.A. giving directions for the use of a new support media in electrophoretic separations. This four page publication gives directions for electrophoretic separations and staining techniques. It also lists advantages of the use of this new material and contains a bibliography of papers published on this subject.

B.D.H. Leaflets.—New entries in the catalogue of British Drug Houses Ltd., Poole, Dorset, are listed in the February 1961 issue of their monthly leaflet. These are: *Organic and Inorganic Chemicals*—Iodine indicator; 6-methoxy-quinoline; sodium diphenyl reagent; solutions for analytical use.

Englass Mouldings.—A brief outline of the varied uses of Englass mouldings is given in a booklet published by the English Glass Co., Ltd., of Scudamore Road, N.P.E., Leicester. These include warning domes, threaded indicator glasses, optical mouldings, precision ground glass balls, solid glass balls, preforms for glass to metal seals, laboratory stopcocks (unfinished), etc.

Bryans Point Plotter.—The point plotter has been introduced into the Bryans range of data plotting equipment to provide a quick and accurate method of plotting points of a graph from tabulated data, when used in conjunction with the Bryans 'X' and 'Y' co-ordinate plotting table. Alternatively, the point plotter can be used as a decade d.c. voltage generator and is invaluable where frequent quick and accurate changes of voltage and polarity are required. A leaflet has been issued by Bryans Aeroquipment Ltd., of 1 and 15 Willow Lane, Mitcham, Surrey, describing this equipment.

Spectrographically Standardized Substances.—Johnson Matthey & Co., Ltd., of 73-83 Hatton Garden, London, E.C.1, have issued a new edition of their booklet 1760, Spectrographically Standardized Substances. The metallic impurity contents, as detected spectrographically, are now uniformly stated in parts per million, and higher purities than previously offered are quoted for many products. Prices of the products, last revised in March 1959, remain unchanged.

MEETINGS FOR THE MONTH

Mid-May to Mid-June

We give below a selection of meetings of interest to laboratory workers. Details are as full as possible at the time of going to press, but readers requiring further information or confirmation of arrangements should contact the organizers.

May 11

The Society of Instrument Technology (Liverpool Section). At M.A.N.W.E.B. Industrial Development Centre, Liverpool. 7 p.m. Annual General Meeting followed by film show.

May 12

Royal Institution of Great Britain. At 21 Albemarle Street, London, W.1. 9 p.m. 'A Crucial Stage in Vertebrate Evolution: Fish to Land Animal,' by Prof. T. Stanley Westoll.

The Society for Analytical Chemistry (Midlands Section). At the Technical College, Nottingham. 7.15 p.m. Joint meeting with the Microchemistry Group of the Society on Automation in the Analytical Laboratory.

May 15

The Society of Instrument Technology (Manchester Section). At the Nag's Head, Jackson Row, Manchester. 6.45 p.m. Annual general meeting, followed by 'The Thermocouple.' An address by the Section chairman, D. A. W. Foster.

May 16

The Institute of Science Technology (London Branch). In the Chemistry Theatre (C.8), University College, Gower Street, London, W.C.1. 6.30 p.m. 'Gathering Scientific Information,' by Mrs. Diana Simpkins.

May 18

The Royal Society. At Burlington House, London, W.1. 4.30 p.m. 'The Transmission of Impulses from Nerve to Muscle, and the Subcellular Unit of Synaptic Action,' by B. Katz, F.R.S.

The Society of Instrument Technology (Newcastle Section). In the Conference Room, Roadway House, Oxford Street, Newcastle upon Tyne, 1. 7 p.m. Annual General Meeting.

May 23

The Society of Instrument Technology (London Section). At Manson House, Portland Place, London, W.1. 6 p.m. Annual General Meeting followed by Presidential Address.

May 25

The Royal Society. At Burlington House, London, W.1. 4.30 p.m. 'The Gravity of a Particle,' by Sir Charles Darwin, F.R.S., and 'The Aerodynamic Theory of Sails,' by B. Thwaites.

June 1

The Royal Society. At Burlington House, London, W.1. 4.30 p.m. 'A Study of the Adoptive Secondary Response to a Protein Antigen in Mice,' by D. W. Dresser, and 'Effect of the Graft-versus-host Reaction on the Immunological Responsiveness of the Mouse,' by J. G. Howard and M. F. A. Woodruff.

June 8

The Royal Society. At Burlington House, London, W.1. 4.30 p.m. 'The Rapid Measurement of Intensity with an Oscillating Fabry-Perot Spectrometer: Isotope Abundance in Mercury,' by D. J. Bradley, and 'Precise Measurements of the Density of Mercury at 20°C.,' by A. H. Cook.

June 9

The Society for Analytical Chemistry (Biological Methods Group). Summer visit to the Biological Laboratories, Research and Standards Departments, Boots Pure Drug Co., Ltd., Nottingham.

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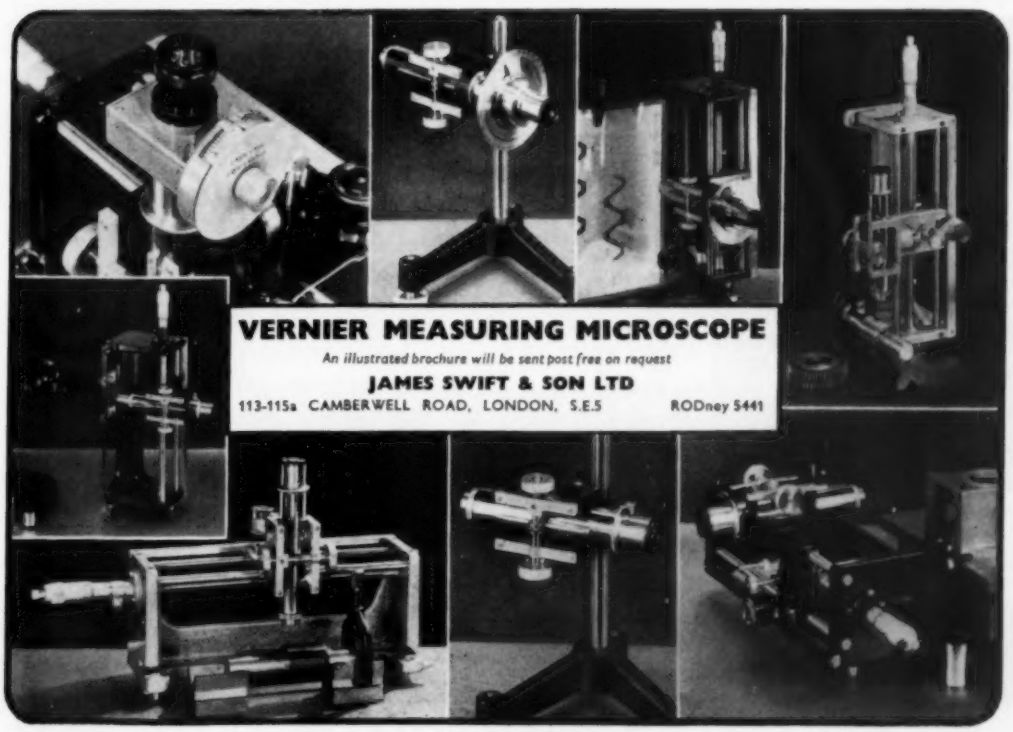
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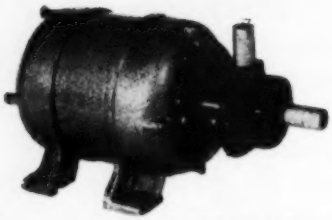

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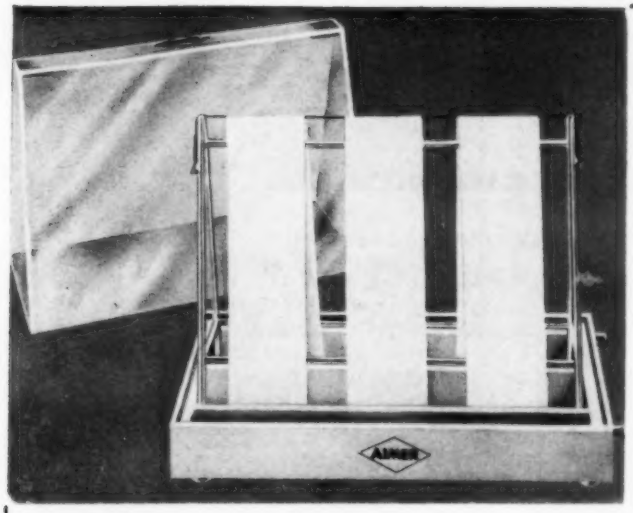

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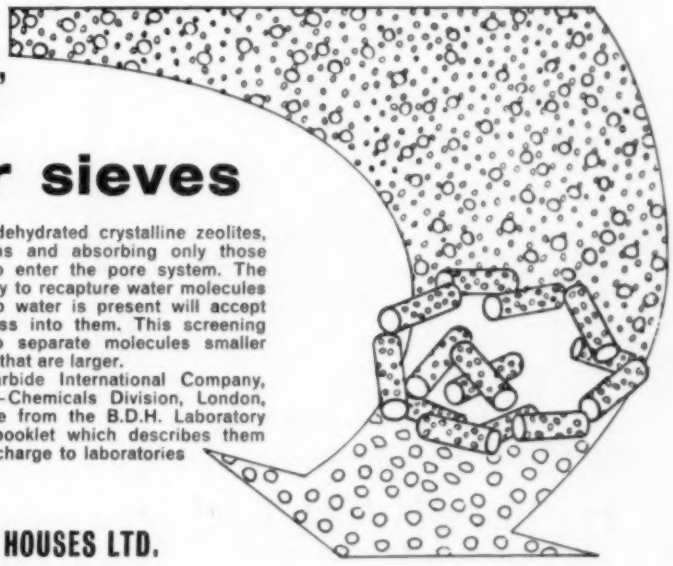

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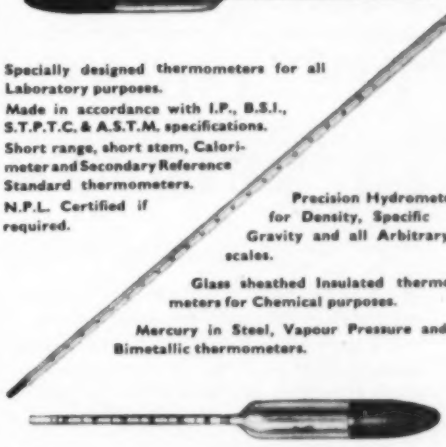

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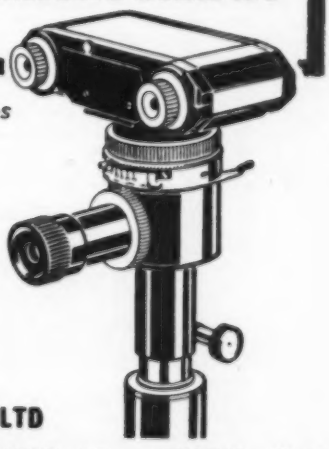

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Apply to Crown Agents, 4 Millbank, London, S.W.1 for application form and further particulars, stating age, name, brief details of qualifications and experience and quoting reference M3C/52927/LAQ.

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Apply in writing, stating age and experience to the

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Enquiries, giving full information about education, etc., should be made in writing to the Personnel Department, Reckitt & Sons Ltd., Dansom Lane, Hull.

SENIOR TECHNICIANS required for newly formed Laboratories at Worthing, concerned with the Development of fermentation and extraction processes in antibiotic production. Good qualifications in Chemistry or Biology to H.N.C., or O.N.C. level essential. Excellent prospects and conditions of employment. Apply in writing, stating age, qualifications and experience to Personnel Officer, Beecham Research Laboratories Ltd., Clarendon Road, Worthing, Sussex.

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The Development Unit is situated in Dorset but a close liaison will be necessary with dairy technologists, chemists, and others at the Board's headquarters in Surrey and their factories throughout England and Wales.

Applications are invited from men in the age group 30-35 preferably graduates or A.R.I.C. but applicants with other suitable qualifications and experience will be considered.

An attractive salary will be paid according to qualifications and experience and there are excellent prospects.

Please write, in confidence, to Chief Divisional Officer, Milk Marketing Board, Thames Ditton, Surrey.

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requires a

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to assist research scientists in fundamental studies of the physical properties of ceramics.

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Contributory superannuation scheme.

Send POST CARD for details to Personnel Manager (1948 120), U.K.A.E.A., A.E.R.E., Harwell, Didcot, Berks.

CLASSIFIED ADVERTISEMENTS

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